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PROF. A. PRESCOTT FOLWELL.

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Local Residence Street with Narrow Roadway, Detroit, Mich. *Frontispiece*

Municipal Engineering Practice

BY

A. PRESCOTT FOLWELL

Past President of the American Society of Municipal Improvements, Member of the National Conference on City Planning, the American Water Works Association, the New England Water Works Association and the Society for Promotion of Engineering Education. Editor of Municipal Journal

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PREFACE

THE municipal engineer is called upon to serve officially in more diversified branches of engineering and allied subjects than probably any other technical man. Of these various subjects he may find sewerage, water supply and street paving quite thoroughly treated in several excellent text-books, but practical information concerning street cleaning, constructing public comfort stations, and a score of other matters is not so readily obtainable. It is possible, also, that this lack of text-books from which these subjects can be taught is one reason, at least, why most of them, although of recognized importance, are not even touched upon by engineering schools in their courses in municipal engineering, and also why greater advance has not been made in these branches of public service.

It was in an attempt to meet this need that this book was written. The aim has been to treat at greater or less length all those matters which more or less frequently enter into the work of the city engineer, omitting entirely, however, the three referred to as already fully covered by existing works. Certain others form the subjects of text-books, but are discussed in them from a point of view other than that of the city engineer. Street lighting, for instance, is generally treated from the standpoint of the electrician; the author has endeavored to treat it from that of the representative of the taxpayer. City planning has been discussed voluminously as a means of creating a "city beautiful"; the aim here has been to point out a practical way to a city efficient, healthful and economical.

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The author claims originality for comparatively few of the ideas presented herein, and yet finds it difficult to give credit for the others. Most of them have been picked up here and there in a rather wide range of reading while teaching municipal engineering and editing "Municipal Journal," supplementing many years of active practice in municipal engineering, which ideas have become so mingled and assimilated that the origin and even the identity of most of them have been lost. In most cases where the source is known it is named in the text. Facts and principles not so credited were furnished by reports of the Pittsburgh and Newark City Planning Commissions, of the Philadelphia Bureau of Surveys, the Baltimore Topographical Survey Commission, and by the 1913 Progress Report on a Plan of Sewerage for Cincinnati. Much of the chapter on "City Surveying" is based upon the publications of the U. S. Coast and Geodetic Survey, Prof. J. B. Johnson's "Surveying," the Cincinnati report above referred to, and reports of the Topographical Bureau of New York City. For a part of the information and most of the illustrations used in the article on "Street-Name Signs" the author is indebted to a bulletin of the Iowa State College Engineering Extension Department, prepared by Rolland S. Wallis. In the article "Public Baths" use was made of Gerhard's "Modern Baths and Bath Houses" in preparing descriptions of certain structural details, especially of the plumbing; but the greater part of this and of the articles on "Markets" and "Public Comfort Stations" was obtained from a study of the plans and construction of modern structures in various cities. For the practical methods described in two or three paragraphs in the article on "Parks" the author is indebted to Prof. Wm. T. Lyle's "Parks and Park Engineering." Finally, many of the ideas presented and a still greater number of the examples cited have appeared in "Municipal Journal," and it is through the courtesy of the publishers of that periodical that the majority of the photographs were obtained which have been used for illustrating this volume.

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Municipal Engineering Practice

CHAPTER I

FUNDAMENTAL DATA

Art. 1. Municipal Engineering—Scope and Aim

Municipal Engineering has as its purpose the planning, constructing and maintaining of the publicly owned physical features and utilities of a city.

Its practices and methods must conform to the laws of nature and those of man—the latter of which may generally be altered if the necessity therefor be convincingly demonstrated.

It should aim to promote, in all of its activities, the health, safety, convenience, comfort and pleasure of the citizens, all with constant consideration of ultimate true economy.

Probably no other branch of engineering requires so diversified a knowledge as this, for there are brought to the city engineering department for solution problems in paving, sewers, water supply, street lighting, bridge and retaining wall construction, stream control, refuse incineration, building construction, electrolysis and numerous other subjects involving practically all branches of engineering theory and practice; in addition to which the department must in many cases handle large forces of men engaged in refuse collection and street cleaning as well as in carrying on construction work of various kinds.

No one man can have an expert's knowledge of all these. But a capable city engineer should have a good general knowledge of the most important; a pretty complete one of the more strictly municipal branches, such as paving and sewers; and sufficient

common sense and moral courage to recognize when he needs the assistance of an expert in any line, and to secure it.

Much the greater part of the municipal engineer's duties have to do with the streets—their surfaces and the structures beneath and above them. Paving, gutters, curbs and sidewalks; street railways; street lighting; wires of all kinds and the poles that support them; fire hydrants, water mains, sewers with their manhole tops in the pavement, wire conduits and their manholes; street line monuments and bench marks—these are some of the material objects with which he is concerned, and on which cities spend about one-third of all the municipal taxes raised in the United States. To properly construct and regulate them he must appreciate the principles and aims and the physical laws involved in their use as well as in their construction.

In the majority of cities, street cleaning is in charge of the city engineer or of a department of public works; and while refuse collection and disposal are still placed by several cities in charge of their health officers, it is coming to be more generally recognized that they have only a remote bearing upon health and that engineers are better qualified than physicians to perform these municipal functions. These subjects are therefore included under the head of municipal engineering.

It sometimes, but not often, falls to the lot of an engineer to select the location of a city and design it with no limitations imposed by existing constructions or street plans. More common is the problem of planning extensions of existing cities or of correcting past mistakes in the older portions thereof. To aid in each of these purposes and because of their general usefulness in studying municipal problems, some fundamental principles of the proper locating and designing of cities and of their growth are presented in this chapter.

Art. 2. Size and Growth of Cities

Few, if any, of the designs of the municipal engineer are or should be made for the present size and physical conditions of a city, but they should be planned to meet the requirements of a

future growth. It is evident that this principle applies to all structures or services which are to endure beyond the immediate present.

Among the general principles to be considered in determining for how distant a future the plans for any structure or utility should be designed are:

(1) No structure or other physical feature of a city should be made of a capacity which will not be reached before the end of its efficient life.

(2) No money should be spent for increasing the capacity of a structure beyond a given point, if the cost of such increase, with compounded interest, would amount, at the time when its original capacity has been reached, to sufficient to rebuild or enlarge that structure to the capacity which the contemplated increase would have provided.

(3) It should be remembered that the future is almost sure to see many, if not most, of the contrivances of the present day supplanted or improved upon, no one can foresee what ones or in what way. Again, the present financial condition of a city may be such that the increased cost required for construction for any but a quite near future would make such construction altogether impossible. When we also consider that predictions of future populations or traffic or directions of expansion cannot be made positively, the desirability of conservatism in providing for future requirements seems unquestioned.

The problem of providing for the future involves both area and population; and it is necessary to consider both the population as a whole and also the density on more or less minute areas.

Present Population. Whether the plans are made for the future or for the immediate present only, the present population must be known or estimated, since it is perhaps the most important factor entering into a forecast of future population. The most reliable, and in fact the only reliable, method of determining present population is by an actual count. The Federal government once in ten years makes such a count of all cities and minor political divisions of the country, these counts being

taken during the early part of the last year of each decade (1900, 1910, etc.). These figures are compiled and published within from one to three years thereafter and can be found in the reports of the Census Bureau, copies of which are available at most public libraries or can be obtained from the Census Bureau at Washington, D. C.

Several of the states take a state census at decennial intervals, generally at the middle of each decade, thus affording census figures for every five years of growth.

Other methods for determining the population of cities are employed by the cities themselves. One of these is by a police census, each of the patrolmen of the city on a given day being required to make house to house calls and determine the number of residents on his "beat." Another is the so-called school census method, by which the records of attendance at the public schools are taken as a basis and an assumption made that the total population is a certain multiple of the school attendance. The ratio between school attendance and population is not, of course, an exact or constant one; and yet there seems to be a remarkable uniformity in this ratio throughout the country, as is shown by the accompanying table. The percentages given

TABLE I

ESTIMATING POPULATION FROM SCHOOL ATTENDANCE

FIGURES FROM THE 1910 CENSUS OF THE UNITED STATES

Geographical Division	Total Population	School Attendance	Percentage of Total Population in School	Percentage of All 5 to 20 Years Old in School
New England	6,552,681	1,222,228	18.7	66.1
Middle Atlantic	19,315,893	3,531,373	18.3	62.9
East North Central	18,250,621	3,576,003	19.6	65.5
West North Central	11,637,921	2,530,591	21.7	67.9
South Atlantic	12,194,89	2,41 ,444	19.9	56.7
East South Central	8,409,901	1,730,191	20.6	57.9
West South Central	8,784,534	1,795,100	20.4	57.1
Mountain	2,633,517	505,191	19.2	65.8
Pacific	4,192,304	700,770	16.7	65.7
United States	91,972,266	18,009,891	19.6	62.3

in this table were obtained by dividing the school attendance of each state by the total population. They are seen to vary from 21.7 in the west north central states to 16.7 in the Pacific states; but omitting these two extremes, the range is only between 18.3 per cent and 20.6 per cent. To estimate the population of any given city by this method, find the ratio between the population as determined by the latest census count, and the school attendance for the same year as determined from the records of the school board, and use this ratio for estimating the population for any other year for which the school attendance is known.

TABLE IA

PERCENTAGE THOSE OVER SIX YEARS OLD ATTENDING SCHOOL ARE OF THE TOTAL POPULATION. NEW YORK STATE.

COMPILED FROM THE CENSUS OF 1910.

	Cities Having a Population of		
	More Than 25,000	10,000 to 25,000	2,500 to 10,000
Number of cities	21	30	97
Average percentage	17.1%	16.6%	16.8%
Maximum percentage	19.7%	23.4%	26.1%
Population of city with maximum percentage	30,919	15,245	4552
Minimum percentage	14.3%	13.4%	12.0%
Population of city with minimum percentage	31,267	12,273	2,517

Another method sometimes employed for determining city population is by use of the business or telephone directory, or "assessed polls." As in the previous method, a ratio is determined between the number of names in such directory or poll list in a census year, and the actual census count made that year, and it is then assumed that the same ratio will hold good for the ten successive years. This is generally less reliable than the school census method, since it is conceivable that the population might increase or decrease very considerably with no appreciable effect on the directory; as when a new industry should be started in the city employing several hundred hands,

few of which would presumably appear in either the business or telephone directories.

Ordinarily the figures for either Federal or state census are those for the population within certain political limits—the boundary lines of the city. For the majority of purposes for which the municipal engineer desires to use such figures, however, political boundaries are of little importance. In the matter of house sewage, for instance, he must generally assume that a given sewer will ultimately be called upon to carry the sewage from the entire area which drains to it, out to the furthest point of such area which will probably be reached by the growth of the city within say fifty years. It may even be that there is already a quite dense population on a portion of this area lying without the city boundary but which in all probability will in a very few years be annexed to the city; in many cases, in fact, it may be served by the city system at once through a special arrangement with the city. The same applies to providing capacity of water mains for supplying all the territory which will ultimately be reached by the distribution system. In the case of a private water company, the position of the city boundary would probably not even be considered in the designing of a distribution system.

In probably every city, the area occupied by a given urban population increases at the same time as, but at a less rate than, the population itself. In general it may be said that the outlying sections of the city always maintain a certain minimum density of population, while the density at the heart of the city increases. As this increased density spreads through the older section of the city it pushes further and further from the city center the ring of minimum density. This process also is only slightly affected by city boundaries, and the ring of minimum density generally progresses slowly beyond such boundary, first at a few points and finally perhaps throughout the entire perimeter of the city, unless outlying areas be annexed to the city's territory in the meantime. The general tendency is to annex such territory at intervals, so that in the long run the

census figures are indicative of the true growth of the city; although the taking of a census just before annexation may cause this census count to indicate a lapse and the next a sudden jump in the growth of the city.

In the case of large cities, the influence of the city may extend to such a distance as to embrace several smaller surrounding communities. This effect is greatly magnified in the case of the largest cities, in that each is usually surrounded by a number of smaller "satellite" cities, each to a large extent or wholly serving merely as a suburban residence place for those whose interests are in the large city. Such territory tributary to a very large city and embracing other cities of no mean size, is called a "metropolitan district" by the Census Bureau, and this bureau has studied the relative growth of such districts and the cities around which they center. The accompanying table, compiled from the census for 1910, shows the areas, for all of the cities of more than 200,000 population, of such metropolitan district, of the city proper and the territory within the district but outside of the city; also the population within the entire territory embraced within a radius of ten miles of the city. It is seen, for instance, that although the population of New York City in 1910 was about four and three-quarter million, that of the metropolitan district was nearly six and a half million. In this case the metropolitan district includes the cities of Yonkers, Mt. Vernon, New Rochelle, in New York State; and Newark, Jersey City, Paterson, Elizabeth, Hoboken, Bayonne, Passaic, East Orange, Perth Amboy, Orange, Englewood, Rahway, in New Jersey; also the village of Mamaroneck in New York and the towns of West Hoboken, Montclair, Union, Kearney, Bloomfield, Harrison, Hackensack, West New York, Irvington, Nutley, Guttenberg, the boroughs of Rutherford and Roosevelt, and the village of South Orange, in New Jersey. Boston's metropolitan district embraces thirty-six cities and smaller municipalities; and that of Pittsburgh, twenty-four boroughs and one city. Detroit's district, however, includes only one additional municipality—Wyandotte, and the districts of Washington, D. C.,

TABLE II

POPULATIONS OF METROPOLITAN DISTRICTS

AREA AND POPULATION OF CENTRAL CITY, METROPOLITAN DISTRICT, AND ADJACENT TERRITORY, IN THE YEAR 1910, OF SEVERAL CITIES OF MORE THAN 200,000 POPULATION. COMPILED FROM THE UNITED STATES CENSUS FOR 1910

District	Population in 1910	Percent of Increase 1900 to 1910
NEW YORK		
Metropolitan district	6,474,568	40.5
In city proper	4,766,883	38.7
Outside	1,707,685	45.9
City and adjacent territory	6,630,599	40.5
Adjacent territory	1,863,716	45.5
CHICAGO		
Metropolitan district	2,446,921	33.1
In city proper	2,185,283	28.7
Outside	261,638	87.7
City and adjacent territory	2,461,764	33.0
Adjacent territory	276,481	81.7
PHILADELPHIA		
Metropolitan district	1,972,342	21.5
In city proper	1,549,008	19.7
Outside	423,334	28.5
City and adjacent territory	2,015,560	21.3
Adjacent territory	466,552	26.8
BOSTON		
Metropolitan district	1,520,470	21.7
In city proper	670,585	19.6
Outside	849,885	23.4
City and adjacent territory	1,543,723	21.6
Adjacent territory	873,138	23.2
PITTSBURGH		
Metropolitan district	1,042,855	31.5
In city proper	533,905	18.2
Outside	508,950	49.1
City and adjacent territory	1,060,707	31.5
Adjacent territory	526,892	48.4
SAN FRANCISCO—OAKLAND		
Metropolitan district	686,873	45.2
In city proper (San Francisco)	416,912	21.6
In city proper (Oakland)	150,174	124.3
Outside	119,787	89.1
Cities and adjacent territory	692,654	46.0
Adjacent territory	125,568	94.0
CLEVELAND		
Metropolitan district	613,270	46.0
In city proper	560,663	46.9
Outside	52,607	37.5
City and adjacent territory	642,355	44.7
Adjacent territory	81,692	31.7
DETROIT		
Metropolitan district	500,982	57.1
In city proper	465,766	63.0
Outside	35,216	5.9
City and adjacent territory	521,233	54.6
Adjacent territory	55,467	7.8

TABLE II—*Continued.*

District.	Population in 1910.	Percent of Increase 1900 to 1910.
LOS ANGELES		
Metropolitan district	438,226	256.1
In city proper	319,198	211.5
Outside	119,028	478.3
City and adjacent territory	468,080	207.8
Adjacent territory	148,882	200.3
WASHINGTON		
Metropolitan district	367,869	20.3
In city proper	331,069	18.8
Outside	36,800	36.5
City and adjacent territory	413,458	19.3
Adjacent territory	82,389	21.7
NEW ORLEANS		
Metropolitan district	348,109	18.2
In city proper	339,075	18.1
Outside	9,034	20.3
City and adjacent territory	367,235	18.3
Adjacent territory	28,160	20.1
KANSAS CITY (MO. AND KANS.)		
Metropolitan district	340,446	49.2
In city proper (Kansas City, Mo.)	248,381	51.7
In city proper (Kansas City, Kans.)	82,331	60.1
Outside	9,734	—25.5
Cities and adjacent territory	391,632	41.7
Adjacent territory	60,920	—0.5
PORTLAND, OREG.		
Metropolitan district	215,048	134.6
In city proper	207,214	129.2
Outside	7,834	530.8
City and adjacent territory	259,745	114.3
Adjacent territory	52,531	70.7
NEW HAVEN		
Total in city and outside	224,901	23.4
In city proper	133,605	23.7
Outside city proper	91,296	22.9
COLUMBUS		
Total in city and outside	221,567	34.7
In city proper	181,511	44.6
Outside city proper	40,056	3.0
BIRMINGHAM		
Total in city and outside	211,961	64.1
In city proper	132,685	245.4
Outside city proper	79,276	—12.6
ATLANTA		
Total in city and outside	208,284	47.7
In city proper	154,839	72.3
Outside city proper	53,445	4.5
SYRACUSE		
Total in city and outside	183,462	21.6
In city proper	137,249	26.6
Outside city proper	46,213	8.8

and Kansas City (Missouri and Kansas) each embraces but one additional city.

In studying the growth of one of these large cities, or of one of the smaller units contained in a metropolitan district, it is necessary, of course, to study the growth of the district as a whole and of its several subdivisions, considering both physical and legal boundaries.

In the majority of cases, however, the problem of the municipal engineer will be concerned with much smaller municipalities, each surrounded by and devoted to agriculture and unaffected to any considerable extent by the growth of any other municipality.

Forecasting population may be done in one of several ways, but preferably by a combination of all. There can be no exactness or certainty in such forecast, but if judgment and comprehensive study be given to the problem an approximation is generally possible which will be of great assistance and probably prove to be within a few per cent of the growth realized.

The increase may be considered as occurring at a uniform rate—the same percentage per year or per decade through successive periods; as arthmetical—the same number of individuals each year; or at a decreasing rate—the percentage of growth each decade being less than for the previous one. The first is generally most applicable to small cities; the last to most of the largest cities, falling gradually to arithmetical increase or even to total cessation of growth (possible of the central city of a metropolitan district). Arithmetical increase is a mean between the extremes of the other two; for which reason, possibly, it is the one employed by the Census Bureau in estimating annual growth between census years.

Calculation by any of these methods begins with a given rate or series of rates as a basis. These rates should be determined as exactly as possible from past records, and from as many of these as are available. Two census counts only may cover a period of growth which is far from typical, owing to annexation, a period of business depression, or any of a number of possible

causes; and four successive counts are the least which can be considered to give reliable conclusions. A city which is not more than thirty years old generally has not settled into a regular rate of growth, and its prospects must be determined in another way.

Probably the simplest method of "smoothing out" the irregularities in rates which the census figures often show is to plot the past populations, using years as one ordinate and population as the other, and pass as regular a curve as possible through the several points or along the center line of the area containing them. This curve is then projected into the future, convex to the year axis (uniform rate), tangent to the end of the curve (arithmetical increase), or concave to the year axis (decreasing rate). The projection is usually done by eye only.

Numerous curves could be plotted, according to the judgment of the investigator, and therefore some make a practice of plotting two which would represent the extremes, projecting these into the future and estimating the future growth as lying between these as a maximum and a minimum limit. The probable growth may be assumed as the mean of these limiting lines; while conservatism in estimating or planning may be attained by using one or the other of them, depending upon the nature of the problems in hand.

To illustrate forecasting by these methods, we may take the census figures for the combined populations of cities of New York state having 25,000 or more population in 1910. The populations by decades from 1870 to 1900 inclusive were 1,972,873; 2,577,720; 3,463,234 and 4,651,462. These are shown plotted in Fig. 1, by the broken line. On the same diagram is shown, by the dotted lines, the Census Bureau method of calculating populations between census years by arithmetical increase.

Instead of drawing a diagram, a method of producing the same result even more accurately, in case there are sufficient figures of actual counts available, is as follows:

Arrange the known figures (for equal intervals of time) in a row, and beneath them the successive differences, and beneath these the successive differences between the numbers

in row two, and so on. When only one number is left in the last line, or if the numbers in a line should all be the same, the last difference is repeated to the right, and a new number is calculated for the line immediately above by adding the lowest difference to the last number appearing in that line; this new number is added to the last number in the line above, and so on

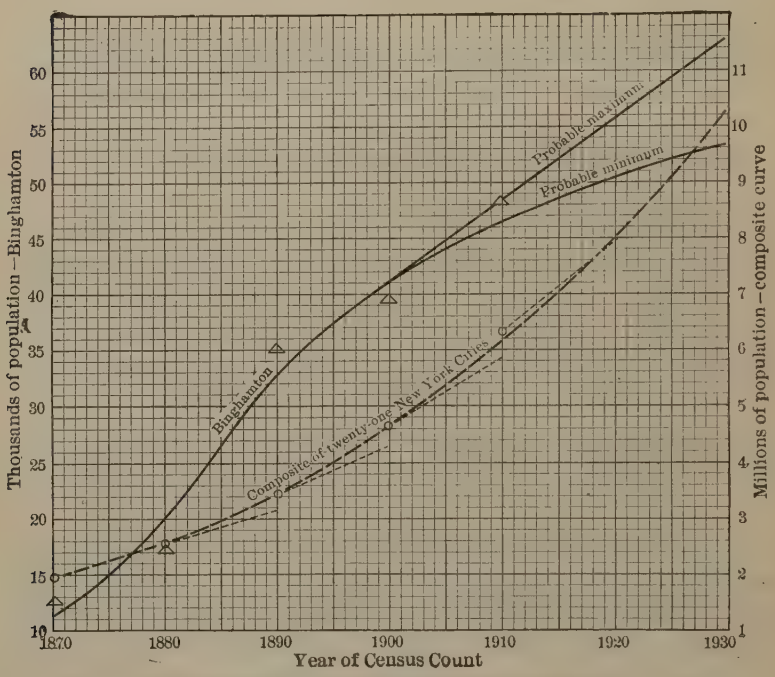


FIG. 1.—Extended Curve Method of Forecasting Population Increase.

until the top line is reached, and this is repeated as many times as desired. (The process is shown performed herewith; the numbers in italics are the ones calculated.) This method can be employed to advantage only when the rate of increase is fairly uniform or uniformly changing.

1870	*1880*	*1890*	*1900*	*1910*	*1920*	*1930*
1,972,873	2,577,720	3,463,234	4,651,462	*6,164,451*	*8,024,248*	*10,252,900*
	604,847	885,514	1,188,228	*1,512,989*	*1,859,797*	*2,228,652*
		280,667	302,714	*324,761*	*346,808*	*368,855*
			22,047	*22,047*	*22,047*	*22,047*

As a matter of fact the census count for 1910 was 6,331,571, or 2.6 per cent greater than the calculation.

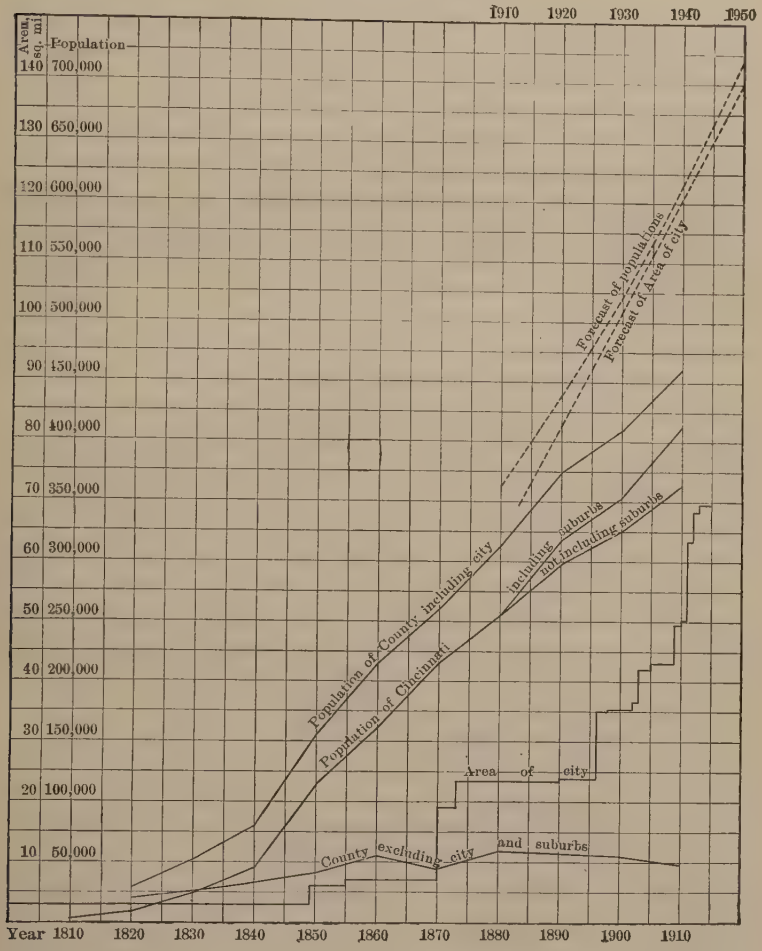


FIG. 2.—Population and Area of Cincinnati, O., 1810 to 1910, and Forecast to 1950. Also population of Hamilton County, of which Cincinnati is chief city.

An illustration of using the uniform rate method would be as follows: Assume that only the census figures for 1870, 1880 and 1890 were available. The rate of increase between 1870 and

1880 is calculated to be 30.6, and that between 1880 and 1890 to be 34.6. Take the average between these, or 32.6, as the uniform *rate* of growth. Then if the increase during successive decades had been at this rate, the populations would have been as follows: 1900—4,592,247; 1910—6,089,319; 1920—8,074,437; 1930—10,706,703.

The figures just used are composites of twenty-one cities and give a rate of growth more uniform than will often be found for a single city. These cities include Binghamton, of which the census counts were 12,692, 17,317, 35,005, 39,647 and 48,443. These are shown in Fig. 1 by the triangles, and the full line is an effort to represent the general rate of increase, which appears to be beginning to decrease.

In making forecasts of population, it should be borne in mind that the history of most large cities has been that their rate of increase itself increases for a time, but ultimately begins to decrease; and that the curve of population, therefore, if carried far enough into the future should take the form of a reversed curve. This tendency of cities to increase in rate of growth up to a certain point and then begin to decrease is indicated by Table III. Omitting the first line, which consists of New York City alone (which city is an exception to many

TABLE III

GROWTH OF CITIES GROUPED BY SIZES. 1880 TO 1910

Cities Having a Population of	Number of Cities in 1900	Average Increase in Population		
		1880 to 1890	1890 to 1900	1900 to 1910
More than 3,000,000	1*	31.2%	37.1%	38.7%
From 1,000,000 to 2,000,000	2	58.9%	39.0%	24.2%
From 500,000 to 1,000,000	3	27.6%	23.2%	16.2%
From 300,000 to 500,000	5	40.6%	27.5%	23.7%
From 200,000 to 300,000	8	47.4%	28.5%	32.5%
From 100,000 to 200,000	17	79.2%	33.3%	41.8%†
From 50,000 to 100,000	40	51.0%	31.0%	41.5%
From 25,000 to 50,000	81	68.7%	32.2%	

*Greater New York. All the area embraced by the present city is included in each calculation of increase.

† 31.1 omitting Los Angeles, whose rate of increase was 211.5%.

rules), and omitting from the cities of from 100,000 to 200,000 the figures for abnormally growing Los Angeles, it is seen that those of from 25,000 to 50,000 showed the maximum rate of growth, and that as the size increased the rate of growth decreased. It is also seen that, except for New York, the rate of growth of the largest cities has been steadily decreasing since 1880, but that in those of less than 300,000 the rate, which decreased between 1880 and 1900, began increasing again between 1900 and 1910. This is an indication of a periodic ebb and flow of urban growth which occurs throughout the country —the world, in fact.

TABLE IV

DECREASING RATE OF GROWTH OF SOME LARGE CITIES

Size of City	Percentage Rate of Growth by Decades						
	Philadelphia	St. Louis	Boston	Baltimore	Cincinnati	Milwaukee	Average
100,000 to 200,000	39.6	103.1	45.5	53.3	52.1	70.0	60.6
200,000 to 300,000	44.6	76.9	44.6	28.1	21.0	41.0	42.7
300,000 to 400,000	51.3	21.5	33.3	28.7	....	....	33.7
400,000 to 500,000	39.7	26.9	24.5	20.3	....	....	27.8
500,000 to 600,000	27.4	24.1	14.9	....	....	....	22.1
600,000 to 700,000	20.0	....	....	....	....	....	20.0

TABLE V

URBAN POPULATION OF THE UNITED STATES AT EACH CENSUS

(NOT INCLUDING HAWAII AND THE SPANISH COLONIES)

A population of 8,000 or more considered as an urban municipality

Year	Number of Places	Percentage Urban was of Total Population	Year	Number of Places	Percentage Urban was of Total Population
1790	6	3.4	1850	85	12.5
1800	6	4.0	1860	141	16.1
1810	11	4.9	1870	226	20.9
1820	13	4.9	1880	91	22.8
1830	26	6.7	1890	449	29.1
1840	44	8.5	1900	556	33.1
			1910	778	38.8

It is impracticable to consider here all of the laws or idio-

syncrasies of growth of cities of various sizes in different sections of the country. In considering any given city, a careful study should be made of the history of the growth of this city and of others of its size and larger in that section of the country, and especially of those larger ones which, when having the size of the city in question, were in general affected by the same conditions which are affecting its growth.

This suggests another method of forecasting growth which has been employed by several prominent engineers. This is, to plot the curve of growth for each of several cities which have been similarly situated as to conditions affecting their growth, and which have already reached a size considerably larger than that of the city in question. Thus, inland cities like Indianapolis, Omaha, Kansas City, etc., would be grouped together; lake cities acting as commercial centers would form another group, and so on. These curves are then moved along the axis of years until they all, including the curve of the city being studied, intersect at a common point, this being the latest population point of said city. From the position of these curves as they now extend across the future year-ordinates, a line can be drawn representing the average growth of these cities as they passed beyond that population; or two lines may be drawn as representing the probable maximum and minimum future population. This method is indicated by the accompanying diagram. It is especially applicable to studying the growth of comparatively new cities.

The influence of neighboring large cities is often an important and even a controlling condition. That the influence of a large city extends further and further beyond its limits as it increases in size is illustrated by the populations of the territory around Manhattan Borough, New York—the original city. The areas which are now included in the boroughs of the greater city have had the growths shown by the accompanying table. It would appear that the influence of the metropolis began to be felt in Brooklyn between 1820 and 1830, and in the other boroughs about ten years later.

The laws and controlling reasons of a city's growth are even more important in forecasting future growth than are figures of

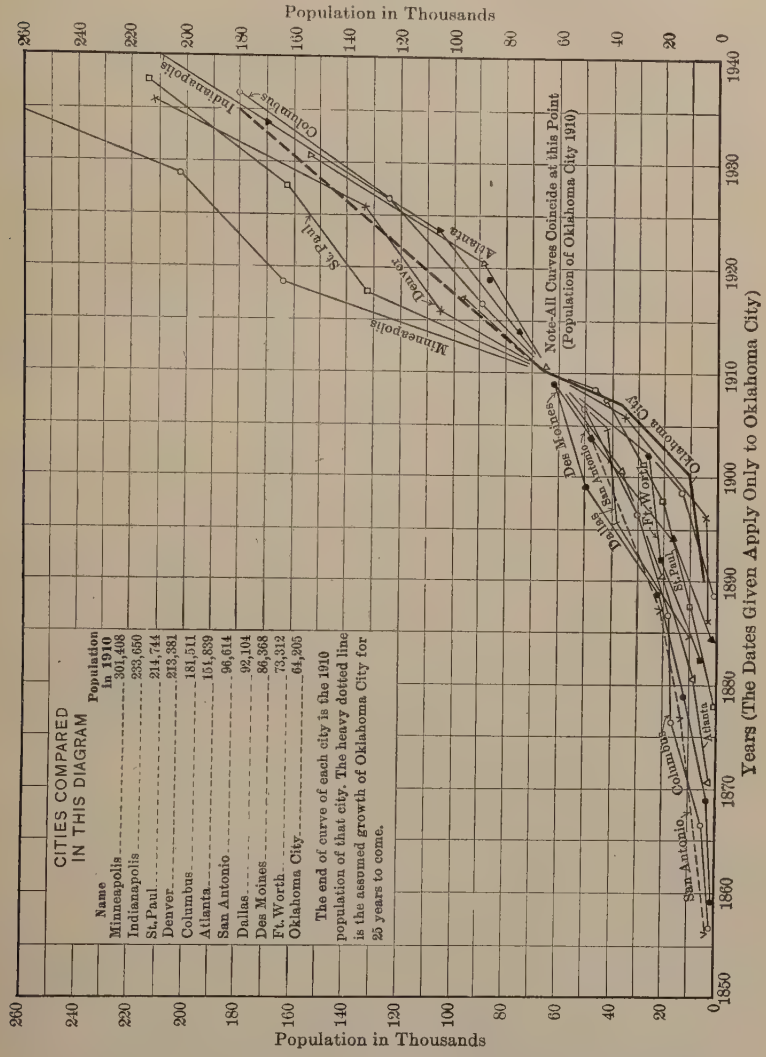


FIG. 3.—Composite Diagram Method of Forecasting Population Increase.

past populations. Cities generally have for years grown faster than rural districts because more of the demands of mankind

are being met by commerce and factories than by farming. The largest cities of all ages have been made so by commerce. The commercial center of a country, a state or a county will be its largest center. Manufacturing cities will generally rank next in size; but frequently attach themselves to the commercial center.

TABLE VI

ESTIMATED PART POPULATIONS OF GREATER NEW YORK CITY AS NOW CONSTITUTED

Year	New York City (Sum of the Other Columns)	Boroughs.				
		Manhattan	Bronx	Brooklyn	Richmond	Queens
1790	49,401	33,131	1,781	4,495	3,835	6,159
1800	79,216	60,515	1,755	5,740	4,564	6,642
1810	119,734	96,373	2,267	8,303	5,347	7,444
1820	152,056	123,706	2,782	11,187	6,135	8,246
1830	242,278	202,589	3,023	20,535	7,082	9,049
1840	391,114	312,710	5,346	47,613	10,965	14,480
1850	696,115	515,547	8,032	138,882	15,061	18,593
1860	1,174,779	813,669	23,593	279,122	25,492	32,903
1870	1,478,103	942,292	37,393	419,921	33,029	45,468
1880	1,911,698	1,164,673	51,980	599,495	38,991	56,559
1890	2,507,414	1,441,216	88,908	838,547	51,693	87,050
1900	3,437,202	1,850,093	200,507	1,166,582	67,021	152,999
1910	4,766,883	2,331,542	430,980	1,634,351	85,969	284,041

A study should therefore be made of the natural circumstances of a city, both in itself and as compared with others which may compete with it for supremacy in its district, to estimate its chances of becoming the commercial or manufacturing center of a district, of how large a district it may become such a center, and the prospects of that district. A few suggestions are added:

Manufacturing tends to concentrate where can be found the best transportation facilities (transportation cost being the most important factor) from the location of the raw materials and to the greatest number of customers. (The latter increases in importance with the bulk of the manufactured articles.)

Minerals (including oil) will attract transportation facilities to them, but will of themselves seldom assure large or permanent populations, except as manufacturing centers there also.

As greater economy and intensity are introduced into agriculture, and international commerce and manufacturing increase, the districts near ocean ports or easily accessible thereto will increase more rapidly than the interior of the country.

Until a district has reached an equilibrium of distribution of population and its normal condition of industry, abnormal and irregular growth may be expected. After this, the cities of the district will continue to increase in size at a rate dependent upon that of the district, and probably higher than the district rate.

There appears to be no reason for setting a limit to the possible ultimate size of a city except that determined by its natural advantages for commerce or manufacture.

Art. 3. Density of Population

This is customarily expressed as population per square mile (for large areas) or per acre (for cities or smaller areas). By population is meant those residing in the area, unless otherwise stated.

The average population per unit area of a state or county, or even of a city, is of little service to the municipal engineer for most of his investigations; but smaller areas such as ward, district, drainage area, or even city block must generally be taken as the unit. Also, for many purposes, he must consider the numbers of individuals assembling on a given area for business or manufacturing or other purposes, which we will call business population to distinguish it from resident population.

Unlike total population (within city boundaries which are being constantly extended), density tends to approach a maximum, and under certain conditions to decrease after having reached it. Fluctuations in density are usually caused by changes in character of the small area under consideration, as from residential to business and from this to manufacturing.

Resident Population. Densities must generally be ascertained by actual counts of individuals on the area in question, although they may be approximately calculated. In either

case, all street areas included in the district and to the center lines of all bounding streets should be included in the area by which total population is divided. Such counts are frequently made by special agents or by the police. If cemeteries, parks, bodies of water and other unoccupied areas are included in calculating density, this should be stated and their areas given.

To calculate density, assume or determine the average size of residence lot, width of street and persons per dwelling. Then

$$D = \frac{43{,}560lbo}{fd\,[lb + w(l + b + w)]},$$

in which D is population per acre.

l " the average length of city block in the area
b " " " breadth " " " " " " "
o " " " number of occupants to a residence lot
f " " " " " front feet to a lot
d " " " " " feet depth to a lot
w " " " width of street.

Example: Given the average block as 400 ft. by 200 ft., streets 66 ft. wide, lots 50 ft. by 100 ft., and $o = 6$. Then

$$D = \frac{43{,}560 \times 400 \times 200 \times 6}{50 \times 100\,[400 \times 200 + 66\,(400 + 200 + 66)]} = 34 \text{ approximately.}$$

For a tenement district, each building on a lot 50 ft. by 90 ft. and containing 80 occupants (all average figures), $D = 525$. (The density of the 17th Ward, New York City, in 1910 was 521.)

A block with lots 25 by 80 ft., six occupants each, represents fairly well the most dense residence section of an average city of 25,000 to 50,000 population, giving $D = 85$.

Actual densities, from counts made for the purpose, are given in Tables VII, VIII, IX and X. New York's maximum density of 523.6 is seen to be several times that of any other city given. Boston's maximum of 190 is about double Chicago's—97.4. Densities in Cincinnati, O., in 1912 varied from 1.4 to 129.7, estimated by wards; but one "precinct" had 272 persons per acre.

TABLE VII

DENSITY OF POPULATION, CITIES OF 100,000 AND UP, 1890

AVERAGE FOR CITY AND DENSEST WARD

(From the U. S. Census of 1890)

City	PER ACRE		PERSONS PER		
	Dwellings	Persons	Dwelling	Family	
Allegheny	3.25	20.66	6.36	5.06	
3d Ward	13.57	93.63	6.90	4.70	Business section; residents of good class.
10th Ward	0.55	2.88	5.22	5.02	Residences of mechanics on high ground.
Buffalo	1.49	10.65	6.86	4.97	
2d Ward	7.71	61.80	8.02	5.84	Mostly business; many hotels. and tenements.
12th Ward	0.21	1.34	6.33	5.81	Suburbs, good class of laborers; park, cemeteries, etc.
Chicago	1.24	10.70	8.60	4.99	
16th Ward	8.07	117.27	14.52	4.78	Polish and German artisans and laborers.
Cincinnati	2.26	20.02	8.87	4.67	
7th Ward	12.19	154.88	12.71	4.08	Centrally located; good class of Germans.
Cleveland	2.75	16.41	5.96	4.93	
10th Ward	8.95	50.31	5.62	4.85	Dense population of laborers in cheap tenements; 77 acres; contains cemetery.
Detroit	2.81	15.63	5.57	4.88	
3d Ward	5.24	29.97	5.72	4.61	Business and manufacturing; railroad yards; negroes, French, Italians, Poles and Germans.
Indianapolis	3.03	15.14	4.99	4.57	
23d Ward	7.69	37.22	4.84	4.64	No description given.
Jersey City	2.23	19.59	8.78	4.73	
3d District	13.75	151.01	10.98	4.79	Residents of moderate means.
Kansas City	1.11	6.39	5.74	4.96	
6th Ward	6.12	39.93	6.52	5.05	Mostly good class of residents. Some Italians and cheap tenements. Gasworks.
Louisville, Ky.	3.16	20.36	6.45	4.89	
3d Ward	6.01	40.04	6.66	4.49	Mostly Germans. Two breweries, market, woolen mill.
Milwaukee	3.02	18.79	6.22	4.92	
2d Ward	6.23	42.53	6.82	4.71	Mostly Germans; some Russians and negroes; brewery and small factories.
Minneapolis	0.76	4.98	6.52	5.01	
6th Ward	5.12	38.14	7.46	4.96	Mechanics, laborers, railroad employees; small section of cheap tenements.
Newark	2.05	15.99	7.81	4.67	
15th Ward	7.92	63.08	7.96	4.37	Irish tenements; a few Italians; a number of shoe factories.
New Orleans	1.81	10.20	5.63	4.98	
6th Ward	8.77	56.26	6.41	5.28	No description given.
New York	.....	.....	18.52	4.84	
10th Ward	13.60	523.6	38.5	4.90	
Pittsburgh	2.17	13.75	6.33	5.33	
7th Ward	19.02	137.26	7.22	5.21	Good class of residents.
St. Louis	1.55	11.50	7.41	4.92	
8th Ward	14.34	143.25	9.99	4.25	Tenements; Russians, Poles, negroes, Italians, Bohemians. Low class of prostitutes.
St. Paul	0.64	4.05	6.35	5.15	
4th Ward	5.14	42.57	8.28	5.76	Business, hotels, tenements; State Capitol, county courthouse, and prostitutes.

Table VIII

POPULATION PER ACRE IN NEW YORK CITY WARDS, 1860 TO 1910

Ward No.	1860	1870	1880	1890	1900	1910	Ward No.	1860	1870	1880	1890	1900	1910
1	118	94	116	72	62	64	13	308	312	353	429	599	664
2	31	16	20	11	18	11	14	292	276	314	293	355	399
3	39	39	38	40	19	20	15	139	139	161	128	122	154
4	265	286	253	215	236	257	16	129	138	149	141	151	160
5	133	102	94	74	49	34	17	220	228	317	312	395	521
6	310	245	234	269	214	210	18	128	118	148	141	136	139
7	202	226	253	290	451	516	19	22	58	107	158	174	198
8	215	195	196	171	159	181	20	152	170	194	190	202	165
9	138	148	170	169	185	215	21	119	138	162	153	147	152
10	273	377	432	524	653	604	22	40	47	73	101	124	137
11	304	328	351	384	505	696	23*	..	..	6.6	12.6	31	63
12	5.5	8.6	14.8	45	87	147	24*	..	..	1.6	2.5	5.3	13.8

* Bronx Borough, annexed between 1870 and 1880.

NOTE.—The wards are numbered consecutively (approximately) from the Battery northward. The 10th Ward is north of Grand street and east of Broadway. The 11th is along the East river south of 14th street, and the 13th is immediately south of it and the 17th immediately west. The section between Broadway and East river, 14th and Grand streets is probably the most densely populated of any city of the world.

Table IX

POPULATION PER ACRE IN CHICAGO, BY WARDS, 1900 AND 1910

Ward	1900	1910	Per cent Change	Ward	1900	1910	Per cent Change
1*	30.4	20.5	−33	19	81.3	90.7	12
2	55.6	53.5	− 4	20	61.6	77.1	25
3	46.3	48.1	4	21*	52.4	49.9	− 5
4	51.1	51.7	1	22*	54.7	51.4	− 6
5	21.5	25.5	19	23*	57.0	55.4	− 3
6	36.1	47.0	30	24	38.8	46.8	21
7	13.2	21.7	64	25	13.1	24.0	83
8	3.6	4.8	33	26	9.3	16.1	72
9	71.8	70.0	− 3	27	2.1	5.5	156
10	74.3	80.8	9	28	31.6	38.7	23
11	51.4	51.5	0.1	29	8.0	12.8	60
12	17.4	31.8	82	30	41.2	40.1	− 3
13	27.1	36.7	36	31	4.5	7.0	54
14	38.5	41.2	7	32	4.7	8.3	75
15	43.9	53.9	23	33	2.9	5.5	91
16	72.8	81.5	12	34	8.3	21.2	155
17	91.9	97.4	6	35	5.7	12.0	112
18	49.1	40.8	−17	Averages	13.9	17.9	28.6

* Lake front business section.

The practical uselessness of "average city density" for application to most municipal problems may be learned from the fact that this density for New York is about 59; for Chicago, 18; and that for Cincinnati has steadily decreased from 36.3 in 1860 to 11.3 in 1910, due to annexation of outlying territory.

TABLE X

POPULATION PER ACRE IN BOSTON, BY WARDS, 1895 TO 1910

Ward	1895	1900	1905	1910
1	17.7	19.2	21.4	24.9
2	60.5	64.2	72.6	80.7
3	42.0	43.9	44.7	46.2
4	44.4	44.0	41.5	44.1
5	62.7	62.0	61.7	61.9
6	95.1	104.3	102.3	122.0
7	43.0	37.5	39.5	37.9
8*	135.0	168.5	180.4	190.0
9	124.5	132.0	118.9	141.5
10	57.2	56.2	60.5	64.3
11	30.0	29.1	33.7	41.4
12	92.0	100.6	92.5	103.4
13	40.7	37.4	35.4	35.3
14	47.4	53.0	54.7	58.2
15	67.2	71.1	73.3	76.6
16	28.9	35.5	38.9	45.6
17	45.8	54.4	52.8	57.4
18	98.6	101.9	100.6	103.3
19	29.4	35.7	38.4	41.7
20†	12.6	19.0	24.4	32.5
21†	30.1	37.3	41.5	50.5
22†	29.3	33.7	36.5	38.1
23†	2.4	3.1	3.5	4.0
24	5.6	8.3	9.7	11.6
25	5.5	7.0	8.0	9.7
Av. Density	20.0	22.7	24.1	27.1

* Low rental tenement houses. † Desirable residential sections.

As in the case of total population, what is desired is generally the maximum density which may occur at any time previous to a certain predetermined date. The changes in density in New York, Chicago and Boston wards are shown by the tables. In each of these cities, certain wards have reached a maximum and begun to dimish in intensity: ex. 5th, 7th and 13th in Boston; 1st, 2d, 4th, 5th, 6th and 8th in New York; and the 1st, 2d, 9th, 18th, 21st, 22d and 23d in Chicago. The congested

TABLE XI

PERSONS PER FAMILY AND PER DWELLING IN 1900 AND 1910

POPULATION	2,500 to 25,000		25,000 to 100,000				MORE THAN 100,000			
	1900		1900		1910		1900		1910	
State	Per Family.	Per Dwelling.	Per Family.	Per Dwelling.	Per Family.	Per Dwelling.	Per Family.	Per Dwelling.	Per Family.	Per Dwelling.
New England										
Maine	4.4	5.1	4.4	6.1	4.6	7.2				
New Hampshire	4.3	4.9	4.9	7.7	4.7	6.8				
Vermont	4.3	5.1								
Massachusetts	4.7	5.5	4.5	6.4	4.7	7.1	4.9	8.8	4.8	8.9
Rhode Island	4.6	5.7	4.7	7.6	4.8	7.1	4.5	6.9	4.6	7.8
Connecticut	4.5	5.3	4.7	7.5	4.7	7.8	4.6	7.1	4.6	7.2
Middle Atlantic										
New York	4.3	5.0	4.6	6.6	4.4	6.3	4.7	11.7	4.6*	12.7*
New Jersey	4.6	5.4	4.7	6.3	4.7	8.0	4.5	8.2	4.6	9.0
Pennsylvania	4.7	5.0	4.7	4.9	4.7	5.0	4.9	5.6	4.8	5.7
East North Central										
Ohio	4.2	4.8	4.4	4.9	4.2	4.7	4.5	6.2	4.3	5.7
Indiana	4.2	4.5	4.5	4.9	4.3	4.6	4.3	4.7	4.0	4.4
Illinois	4.4	4.8	4.6	5.1	4.3	4.8	4.7	8.8	4.6	8.9
Michigan	4.5	4.9	4.3	4.7	4.2	4.6	4.7	5.5	4.4	5.4
Wisconsin	4.6	5.0	4.8	5.3	4.7	5.3	4.8	6.2	4.6	6.2
West North Central										
Minnesota	5.0	5.3	5.3	6.5	5.3	6.6	5.0	6.5	5.0	6.5
Iowa	4.3	4.4	4.5	5.0	4.4	4.7				
Missouri	4.4	4.7	4.5	4.8	4.2	4.5	4.5	6.7	4.3	5.2
North Dakota	4.9	5.6								
South Dakota	4.7	5.1								
Nebraska	4.5	4.7	5.2	5.9	4.6	5.0	4.9	5.7	4.7	5.2
Kansas	4.3	4.5	4.2	4.7	4.1	4.4				
South Atlantic										
Delaware	4.3	4.3	4.7	4.9	4.7	5.1				
Maryland	4.6	4.8	...	...	...	...	4.8	5.7	4.7	5.5
Dist. of Columbia	...	...	...	...	...	...	4.9	5.6	4.6	5.7
Virginia	4.7	5.3	4.7	6.0	4.7	5.4	...	...	4.7	5.7
W. Virginia	4.8	5.1	4.5	5.5	4.5	5.3				
N. Carolina	4.5	5.1	...	...	4.4	4.8				
S. Carolina	4.8	5.2	4.0	6.4	4.2	5.7				
Georgia	4.3	4.9	4.2	5.2	4.0	4.6	...	...	4.3	5.1
Florida	4.4	4.7	3.9	4.5	4.5	4.8				
East South Central										
Kentucky	4.5	4.9	4.5	5.5	4.1	5.1	4.6	5.9	4.3	5.4
Tennessee	4.7	5.2	4.5	5.3	4.4	5.1	4.6	5.6	4.2	4.9
Alabama	4.4	4.8	4.3	5.2	4.1	4.6	...	...	4.3	4.9
Mississippi	4.4	4.9								
West South Central										
Arkansas	4.4	4.7	4.6	5.2	4.5	4.8				
Louisiana	4.5	4.8	...	...	4.2	4.6	4.6	5.4	4.6	5.0
Oklahoma	4.5	4.7	...	...	4.6	5.3				
Texas	4.7	4.9	4.7	5.1	4.6	5.0				
Mountain										
Montana	4.8	5.1	4.7	5.4	4.6	5.2				
Idaho	4.3	4.6								
Wyoming	5.2	5.5								
Colorado	4.2	4.5	4.5	4.9	4.4	4.6	4.3	4.9	4.2	4.8
New Mexico	4.0	4.4								
Arizona	4.4	4.6								
Utah	4.9	5.1	4.5	5.2	4.6	5.2				
Nevada	3.8	3.9								
Pacific										
Washington	4.6	4.8	5.1	6.1	4.6	5.2	...	...	4.6	5.3
Oregon	4.3	4.7	5.4	6.2	...	...	...	...	4.9	5.5
California	4.2	4.4	4.4	4.8	4.0	4.4	4.6	5.9	4.3	5.3

*4.5 and 6.2 omitting New York City.

wards in New York increased in density 8.8 per cent between 1870 and 1880, and 0.5 per cent between 1880 and 1890; while during the same periods the uncongested wards increased 54.4 and 49.9 respectively. In Philadelphia the congested wards lost in population by 7.9 per cent between 1870 and 1880, and by 1.2 per cent between 1890 and 1900, and gained only 1.5 per cent during the intervening decade; while the uncongested wards increased 87.3, 43.5 and 10.9 per cent during the same successive decades. During the decade ending 1891, the several boroughs of inner London (England) lost as follows: "City," 25.5 per cent; Westminster 19.9 per cent; Strand 18.2 per cent; St. Giles 12.1 per cent; Holborn 6.8 per cent; Shoreditch 2.0 per cent Whitechapel, (gain) 4.3 per cent. On the other hand the suburbs all gained from 26.1 per cent to 133.5 per cent during the same decade.

TABLE XII

SIZES OF FAMILIES, 1850 TO 1910

	1850	1860	1870	1880	1890	1900	1910
United States	5.55	5.3	5.1	5.0	4.9	4.7	4.5
N. Atlantic Division	5.45	...	...	4.8*	4.7	4.6	4.5
N. Central Division	5.69	...	...	5.1	4.9	4.6	4.4
Western Division	4.18	...	...	4.7†	4.9*	4.4	4.5
Virginia	...	...	5.3	5.4	5.4†	5.1	4.9
N. Carolina	...	...	5.2	5.2†	5.3†	5.1	5.0
New York City	...	...	...	5.0	4.8	4.7	4.7
Brooklyn	...	...	...	4.9	4.7	4.6	4.6
Philadelphia	...	...	...	5.1	5.1	4.9	4.7
St. Louis	...	...	...	5.4	4.9	4.6	4.4
Chicago	...	...	...	5.2	5.0	4.7	4.6

* Increase in female population. † Negro population.

The tendency is for each district to approach a maximum density which depends upon the use to which the district is devoted or may be devoted. The problem generally is to estimate what such maximum density will be. It is frequently complicated by changes in the use of the district. "The original settlement becomes the business center and for some time continues to grow rapidly. But if the city prospers, the time will come when this old center is more and more needed for strictly

business purposes; houses disappear before the march of office-buildings, government buildings, banks, etc., until the only residents left are the janitors and *portiers*, the keepers of the great buildings. With continued growth, the business center extends itself and steadily pushes the dwellings toward the circumference, until at length the municipal limits are reached and passed." (The Growth of Cities, A. F. Weber.) The 2d Ward, New York, (an office building district between Peck Slip and Maiden Lane) contains a less dense population than any other ward in Manhattan island; and the 3d Ward, between Liberty and Reade streets, is less densely populated than any of the residence wards except the 23d and 24th. A strictly business district in any city is likely to lose rather than gain in population, and to extend its area of diminishing population as the city grows.

The forecasting of densities will generally require, as a preliminary, the assumption of what areas will, within the assumed time limit, be occupied by business center, what by residences, etc.; and what will be the maximum density for each of such districts. The location of such districts is considered in Article 4. The density of each can only be calculated approximately by study of local conditions and of similar cities in the same section of the country. Street widths have considerable effect on density figures, as in some cities only 25 per cent and in others 50 per cent of the land area is in streets. This partly accounts for the greater densities in eastern than in western cities, the streets being generally wider in the latter. The table of average numbers of persons per family and per dwelling in the several states in large, medium size and small cities will assist in the calculation. A past record of ward destinies in the city in question will indicate whether the business center has reached its maximum. The other areas will probably increase in densities, except such as may be taken, in part or in whole, for parks, railroad yards or other uninhabited areas.

For congested districts in eastern cities the author suggests the following for general averages, in lieu of estimates based on

specific figures for the place in question. West of the Ohio river and in the southern states probably one-half of these would be sufficient.

Until the city exceeds	25,000	75	per acre
Between	25,000 and 50,000	100	" "
"	50,000 and 100,000	150	" "
"	100,000 and 250,000	200	" "
"	250,000 and 500,000	250	" "
"	500,000 and 1,000,000	350	" "
Over	1,000,000	500	" "

Congested districts will ordinarily be found immediately surrounding the business center, and will be pushed outward by it as it expands.

For transportation and manufacturing districts, the population may be given a nominal density figure of ten within the yards, factory grounds, etc. Immediately surrounding these will frequently be the residences of the laboring classes employed in them; although this will depend upon topography and the relative position of the business center in many cases.

The sum of the assumed area populations (area times density) should exceed the total population of the city assumed for the time in question, or the total of all the areas considered; for there is more uncertainty as to the future growth of any given area (except perhaps business, transportation and manufacturing) than as to that of the city as a whole. By how much such sum should exceed the total assumed population will depend upon the confidence felt in the density assumptions and upon what degree of conservative amplitude in the calculations may be called for by the nature of the problem under consideration.

Business Population. The above refers to resident population. An estimate of future business population is even more difficult since it varies with the kind of business and the height of the building, in addition to the conditions affecting resident population. One office building in a large city may contain more persons during the day than any three acres of residence

area in the city. An office building may have an occupant for each 60 to 200 square feet (this including allowance for halls, elevators, etc.) on each floor; a factory one for each 30 to 200 square feet. (New York's labor law requires a floor area of 32 square feet for each employee in fire-proof buildings, 36 square feet in non-fire-proof).

The total floor area will of course be that of the building times the number of floors. What the latter will be will depend upon the size of the city, value of land and local custom. The height to which buildings may rise above the sidewalk level in several cities is shown in the table:

TABLE XIII

HEIGHT TO WHICH BUILDINGS ARE RESTRICTED BY LAW IN SEVERAL CITIES

Baltimore	175 feet	Portland, Ore.	160 feet
Boston[1]		Rochester[2]	
District A	125 "	Scranton	125 "
District B	80–100 "	Youngstown[1]	
Buffalo[2]		Fort Wayne[1]	200 "
Charleston[1]	125 "	Providence	120 "
Chicago	200 "	Salt Lake City	125 "
Cleveland[1]	200 "	Toronto[3]	130 "
Erie[1]	200 "	Washington, D. C.	
Indianapolis	200 "	Pennsylvania Ave.	160 "
Los Angeles	150 "	Business Streets[4]	130 "
Manchester, N. H.	125 "	Residence Streets[5]	85 "
Milwaukee	225 "	Seattle	about 20 stories
New Orleans[1]	160 "		

[1] Not to exceed 2½ times width of widest street.
[2] Not to exceed 4 times average least dimension.
[3] Not to exceed 5 times least dimension at base.
[4] Not to exceed street width plus 20 feet.
[5] An intermediate height between 60 feet and 85 feet on streets over 70 feet wide—height not to exceed width of street minus 10 feet; 60 feet on streets from 60 to 70 feet wide; and street width on streets less than 60 feet wide.

The height of each floor will generally be from ten to fifteen feet, including thickness of floor construction. Buildings in this district may occupy 90 per cent of the area exclusive of streets, or say two-thirds of the total area. The density in a large city may reach 5,000 or more per acre.

In a city whose occupants find all their business interests within it, we may assume, as a condition of maximum density, that all of the male population between the ages of fifteen and

sixty, and half the female between fifteen and forty, are in business in some capacity. According to the census of the United States for 1910, this would give 32 per cent of the total population for the males and 10 per cent for the females, or 42 per cent engaged in the business and manufacturing districts during the day. If we set the age limits as twenty to sixty and twenty to thirty respectively, and only one-fourth of the females in business, we have 27 per cent for the males and 3 per cent for the females, or a total of 30 per cent of the population. Allowances for the sick, the retired, clergymen, etc. would probably about balance those continuing in business after the age limit assumed. As in estimating densities of resident population, the total business population may be assumed as spread over the business area at various densities and the sum of the area population should exceed the total.

There will be special cases calling for special treatment, such as homes of railroad employees, mining towns, etc., where few of the occupants spend their working hours in the town. Density in manufacturing plants will depend largely on the kind of manufacturing—much less, for instance, in a foundry than in a factory where each employee works at a small machine. There are few figures available to assist in such calculations.

In estimating business population on a basis of total resident population it should be borne in mind that the resident population of the metropolitan district must be used and not merely within the corporate limits of the city proper.

Art. 4. City Districts

For many purposes it is necessary to consider the use to which a given area is being put or is to be put within the space of a given future. As just seen, the density of population of a given area is largely a function of the nature of the use made of it; but also the size and kind of sewer, kind of street paving, spacing and intensity of street lighting, and many other municipal structures and services will vary with the use of the district in question.

A division may be made of a city into retail business, wholesale business, manufacturing, transportation and amusement districts, in addition to the residence; which last will always be the largest, and may be divided into sub-districts occupied by the wealthy, by the poor and by the large middle class; or into those built solidly in blocks and those entirely surrounded by grounds, or on several other bases. In many of the smaller cities and villages there are no special districts devoted to any of these unless it may be the transportation; and in even the largest the amusement (other than parks) and retail districts generally occupy much the same territory.

The transportation districts are perhaps the most definitely fixed and their future as well as present location can be decided with the greatest certainty. They center about railroad freight stations and docks of water ways, and may contain, besides these, warehouses, grain elevators, coal and lumber yards, railroad shops, ship yards, and generally a cheaper class of stores, saloons, hotels, etc. Transportation, factory and wholesale districts are combined on the same area in many cities. The transportation district will naturally be confined to the water front and to the location of the railroads, the former being always and the latter generally the lowest land in the city. A railroad follows the bottom of a valley or bank of a river if such pass through or by the city. Only in the case of a city on a plain or gently rolling country to which new railroad lines may be built will the location of the transportation district be uncertain.

Manufacturing districts will generally locate on low, flat land to secure easy hauling to and from the transportation district and low cost of constructing large buildings; near water power, if there is any; and, if they require any considerable area of land, where this is cheapest. Manufacturing tends to center around the intersection of transportation routes and follow each as it radiates therefrom.

The retail district locates where it can be most central and most readily attract large numbers of customers. In many of the largest cities there have been several retail districts scattered

over the wide area of the city, but modern business tendencies together with improved methods of local transportation are resulting in the concentration of this business around one center. If a village or small city centers around the intersection of two main roads, this will generally be the focus of business, and stores will extend out both roads, but furthest along the most traveled one. This will generally apply to trolley roads also, where these follow a public street, but not to steam railroads, canals or other freight carriers. The retail center seldom locates adjacent to a railroad station, although a passenger station may penetrate to the retail section. If it can be determined, therefore, where the main arteries of foot, carriage and trolley travel will be, the intersection of two or more such routes will be a logical center of retail business; and it will almost invariably be true that any attempt to arbitrarily locate any kind of business in any but its logical center will ultimately fail, and will retard the development of such business in the city.

Wholesale business depends upon a less number of customers and these largely men; it therefore locates further from the residence sections, generally between the retail section and the freight transportation stations. It is generally smaller in area than the retail district, and is more apt to be divided into sub-areas, grouped near the centers of transportation, where there are several such.

Amusement and entertainment establishments are generally located in the retail districts, although they may in large cities become more or less grouped into sub-districts. This does not refer to "resorts," picnic grounds, "parks," and the like, which generally keep beyond the limits of the actual city.

Residence districts generally surround the others—on all sides, if possible. Should a residence section become surrounded with one or more districts of another kind, the population will generally become highly congested, until the land becomes more valuable for business or manufacturing purposes than for residence, and is taken over for such purposes. (Tenement laws may restrict the permissible residence congestion and hasten

the transformation.) A residence section seldom becomes badly congested which has room for expansion on two or more sides. In general, the nearer the business or manufacturing districts and the more sides they touch upon, the denser the population, other things being equal. *Nearer* is to be taken in the sense of time and convenience of transportation rather than of space; consequently speed, frequency and convenience of passenger transportation are important.

The more attractive a residence site, the sooner it will be occupied and the more rapidly it will grow. This attractiveness involves salubrity; adaptability to building purposes of the slope and soil (whether of rock requiring blasting, etc.); picturesqueness; absence of objectionable features nearby, such as quarries, slaughter houses, gas works, etc. (although these often determine the character of residents rather than repel them altogether). A site originally objectionable may be transformed into a very attractive one by removal of objectionable neighbors, by draining and filling of low lands (ex. the "Back Bay" of Boston), by landscape gardening, construction of parks, boulevards, etc.

In a forecast of the population etc. of Cincinnati, it was believed by the engineers that in 1950, 9 per cent of the city's area would be given over to manufacturing, 0.8 per cent to commerce, 0.2 to transportation, 2.8 to parks and cemeteries and 87.2 per cent to residence.

The most congested residence district is almost invariably that occupied by the poorer, "laboring" classes; and to save transportation cost and to be near the diversions of the city center and their fellows, most of these locate near the business center. Next to these in position and density come the "middle class" residence districts; while along the perimeter of the city and in the suburbs live those of both the rich and middle class who wish rural surroundings. Each of these is pressed outward as the city grows.

Improvement Districts. In some states it is compulsory and in others optional that cities which assess property for public

improvements divide the city into sewerage or drainage districts, paving districts or other improvement districts; all the property in each district being assessed for each piece of work done in that district. The boundaries of these districts are sometimes made coincident with the ward lines, but this is not logical and in some cases, as for drainage, is impractical. Ward lines are conveniently and properly run along street center lines, but to divide improvement districts by such lines is generally to divide a sewer, a roadway pavement, etc. between two districts. An improvement district line should run between two streets to which it is approximately parallel, being approximately equidistant from them, but following property lines for convenience where these approximate such location.

For sewers, each district should embrace all the area which drains toward one main sewer (including such main sewer) and exclude all which drains toward another. As sewer grades do not always fall in the same direction as original surface or even as street grades, a correct subdivision into sewer districts can not be made from surface indications only but requires that the sewer system first be designed. Otherwise a convenient and economical design might be rendered legally impossible because not discovered until after the districting.

Each paving district should include all the minor streets tributary to a thoroughfare, and the thoroughfare itself, so as to distribute the cost of the more expensive thoroughfare among a proportionate number of the dwellers on minor and more cheaply paved streets. This is generally effected by laying out a district line equidistant between parallel or radiating thoroughfares, thus including in each district one thoroughfare and the minor streets on each side of it extending half way to the next thoroughfare. Where there are two or more successive parallel thoroughfares, a district may be laid with its longest axis normal to such thoroughfares and extending for some distance beyond them, so that an equitable amount of inexpensive pavement may be combined in a district with these expensive ones.

CHAPTER II

THE CITY PLAN

Art. 5. General Principles

By the city plan we mean the ground plan—the general layout of the streets, parks and other subdivisions of the city's area.

An ideal method of planning a city would be to have a plan providing for the growth for some years to come, prepared by a commission of competent engineers, landscape gardener and architect. Several cities have approximated this, although few have placed more than a limited area in the hands of such a body of experts.

But at least there should be a skeleton street plan for every town, however small. The main thoroughfares are for public use and convenience and their planning should not be left to property owners with only personal gain or convenience in view and with no regard to how streets on adjoining property have been or may be laid out.

Certain streets are used by the public at large (called generally thoroughfares); others are seldom used except to reach the residences on them (local residence streets); while intermediate are various grades of residence and business streets. The first should undoubtedly be laid out by a public authority; the second may be left to private planning, under certain general restrictions; while the others may occupy an intermediate position, the planning of them by private parties being subject to varying degrees of control.

In the street plan ample provision should be made for the future. A commission which planned New York in 1806 did not believe that the city would reach in three centuries a terri-

tory which was thickly populated one century later. L'Enfant's plan for Washington, D. C., prepared in 1791, was considered visionary in extent; but about one hundred years later a commission prepared a street plan for forty-five square miles of additional territory to receive the overflow from the original fifteen square miles. The effect of the street plan upon the plans for drainage and sewerage and the direction and even extent of growth of the city's business may be considerable and decisive of its welfare.

In designing any municipal structure or service, Health, Convenience, Economy, Comfort and Pleasure should be considered, generally in the order given; although pleasure and comfort may properly precede convenience in residence and certain other districts.

Health calls for abundant fresh air and light, which are excluded from narrow streets and alleys, from short blind streets and by frequent sharp turns; also from "back tenements" in the interiors of blocks, which generally result from planning blocks larger than the character of the district warrants. Light is more uniformly and generally distributed where the streets do not run due east and west. Dry soil is necessary, and to secure this it may be best to locate a street in a drainage channel leading from every low spot or even to create such a drainage street from a natural basin by cutting; and to raise low ground by filling in. Healthful recreation is furnished by parks and playgrounds.

Convenience demands that the greatest possible number of citizens be given facilities for reaching quickly points where business or inclination calls them, and with the least effort.

Economy requires a consideration of how the other qualities may be secured with the least annual cost of interest, sinking fund and maintenance, bearing also in mind the limitations of the city's present financial condition.

Comfort is given by shaded streets on easy grades; by clean, dry roadways and sidewalks; by "latrines" or public comfort stations; by seats in parks and at waiting stations for cars,

cabs, etc.; by street lights; and in numberless details of street construction and appurtenances, and of their maintenance.

Pleasure as well as health calls for the providing of parks and playgrounds, public baths, recreation piers and other forms of public diversion. Also the satisfying and training of the aesthetic tastes of the people by artistic parks, monuments, arches, etc.; by avoiding a stiff and wearyingly monotonous street system; and by the prevention of anything offensive to sight, hearing or smell.

Intelligent designing of a city plan requires consideration of the location and alignment of the streets, individually and in relation to each other; their grades; width of roadway and of sidewalks; sizes of blocks; location of parks, cemeteries and public buildings; treatment of streams and water fronts, and numberless other details.

The purposes of streets are: To act as thoroughfares for passing from one place to another; as means of access to buildings and grounds facing upon them; as open spaces to admit light and air to adjacent buildings. They also serve many secondary purposes, such as carrying off surface water in their gutters or in sewers; carrying under their surfaces such sewers and those for house drainage, water pipes, steam heating mains, etc.; and on their surface, street railways, shade trees, letter boxes, telegraph wires and numerous other public conveniences. Some large cities have considered their use as playgrounds for children a legitimate one in the absence of available parks.

Art. 6. Skeleton Street Plan

Main Thoroughfares. Streets vary greatly as to the percentage of the total population using them. Some carry great numbers daily and hourly to and from centers of business or pleasure; other streets are seldom used for any purpose except to reach the houses directly facing thereon. The first are main thoroughfares, the latter, local residence streets. Intermediate between these are secondary thoroughfares, both business and residence, and minor business streets.

The chief purpose of main thoroughfares is to enable citizens generally to pass readily from place to place. The convenience and other services rendered to the abuttors is a secondary consideration. On the other hand, local streets are primarily for the service of the abuttors and only distantly for any public purpose. Consequently the location, grade, pavement and other details of the former should be determined by public officials or representatives; while the latter class of streets may be under municipal control to a much less degree.

Thoroughfares should be designed to provide transit rapidly and conveniently between points of assemblage, and from these to residence centers. They should therefore be as straight and level as possible. Since their location is most important, they should be the first streets to be laid out in preparing a street plan; and since their use is primarily a public one, they should be located by public and not by private initiative. Straightness of line should be given greater weight than grade when the latter can be remedied by cutting or filling whenever this may become sufficiently desirable; but where grades cannot be reduced (as in mounting to a higher level), grade is even more important than line for horse or automobile traffic, although possibly not always for street railway and foot traffic. Two routes, one short and steep, the other with easy grades, are desirable in such cases.

The principal terminus of main thoroughfares is the business center of the city—the point where the largest numbers of people congregate daily. There will be other centers for thoroughfares, such as factory districts, freight stations, parks and other pleasure centers. In the majority of cases most of these centers have already become established. If they have not, their probable location should be determined by principles already discussed.

Other points along the routes of main thoroughfares will be fixed by the location of practicable bridge sites for crossing rivers; gaps or notches in hills to be crossed; valleys which, if followed, will make steep grades unnecessary, etc. Thorough-

fares should lead in all directions to the surrounding territory so as to tap all residence districts. At least one should connect directly with each road from neighboring cities and towns.

FIG. 4.—Unsightly Angle in Street.

If straight lines cannot be obtained for main thoroughfares, there should be as few bends as possible, and these in long, sweeping curves. Angles may be necessary, but are objection-

FIG. 5.—Objectionable Wiggle in Street Line.

able. Jogs or sharp offsets in the line should be avoided at all cost; they are dangerous for traffic and annoying to those in a hurry—as most users of the thoroughfare will be.

It is apparent that the above can be followed only by designing a series of lines radiating in all directions from each principal center. This is known as the radiating system. It is found fully developed in few cities of this country; but, on the other hand, few cities have no radiating streets.

The most common street system in the United States is that known as the "checkerboard," "gridiron" or rectangular system, in which all streets form sides of rectangles and are continuous from side to side of the city. The use of "ring" or circumferential streets is by some classed as a system, but seems to the author to be but a variation of the diagonal. A ring street surrounds the business center of a number of cities, the idea being to girdle the most frequented district of the city by a street to which all outside streets will lead and from which any part of said district can readily be reached. A series of more or less concentric ring streets is generally desirable, as explained later.

The rectangular system has the advantages of simplicity, convenience of subdivision into rectangular lots and of locating and surveying property, greatest possible economy of street area, and ease of finding one's way about the city. The great disadvantage is the distance necessary to travel in crossing the city diagonally—the absence of the diagonal main thoroughfares. The radiating system gives short routes for diagonal travel; an increased number of streets leading to centers of assemblage, thus alleviating traffic congestion; increased length of street frontage within a given radius of the center, and greater territory available and desirable for retail business (which business does not generally extend more than one block each way from main thoroughfares).

Broadway, New York, and Market street, San Francisco, are illustrations of the tendency of retail business to follow diagonal thoroughfares and also of the effect of these on property for a block on either side.

Another advantage of radiating streets is the greater amount of light and air admitted to a district where the crowding of tall buildings and the congregating of people render this especially

desirable. The principal disadvantages of the radiating system are the additional land devoted to streets and thus rendered unavailable for building purposes, and the oblique angles at intersections. The latter is not at all serious in practice if handled intelligently; the acute angles will often bring even higher rental per square foot than other corner property, being especially adapted to the sale of articles not bulky and in popular demand, such as cigars, newspapers, drugs, and for corner groceries, saloons, etc. The decreased building area will be considered in a following paragraph.

A combination of the rectangular and radiating systems possesses many of the advantages of both. It can be secured where the former already exists by the intelligent location of a number of diagonals cutting through existing blocks.

Given a city laid out in rectangular blocks 560 by 250 feet (see Fig. 6) with streets 60 feet wide, except the thoroughfares, which are 80 feet, and consider an area 6100 feet square, with the center of traffic in the center. Insert the two diagonals between corners. Then the distance necessary to travel to reach the center from the corners is 29 per cent less by the diagonals than by any other route, and by use of the diagonal the distance traveled may be reduced by a less percentage for every point in the city except those within a block of one of the two original streets passing through the center.

If we now insert other radial streets intermediate between the original rectangular axes and the diagonals, the maximum increased saving in distance for any point is 7 per cent. This saving might be worth the cost in some cities, but not in many.

In the original rectangular plan, the streets occupied 27 per cent of the total area of the city. The diagonal streets will occupy but $2\frac{3}{4}$ per cent additional area; to offset which, they furnish an additional 6 per cent frontage, all on thoroughfares and therefore above the average in value.

Another advantage of diagonals is that, within a given distance from the center, measured along the streets, we will have about 50 per cent more frontage. Also if all the blocks

which the diagonal thoroughfares cut across were withdrawn from use for building and made into parks, the remaining frontage which could be reached in a given time or with a given distance traveled would still be about 14 per cent greater than without

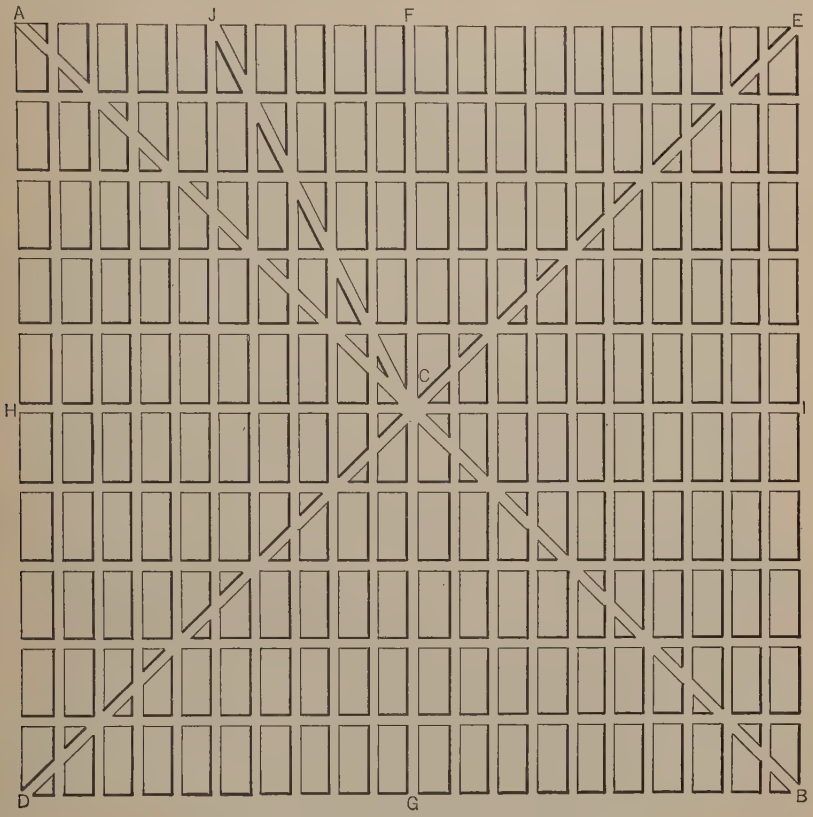


FIG. 6.—Diagram Illustrating Use of Diagonals.

Diagonals *AB* and *DE* intersect at the center of *C* of the rectangular system. Another diagonal, *JC*, may be located midway between *A* and *F*, but is of minor advantage, as explained in the text.

the diagonals; and it is not nearness "as a bird flies," but the distance to be traveled to reach the "center of things" which determines land values and density of population and of business. Diagonals therefore tend to relieve congestion of both residence and business districts by enlarging their areas.

They, however, increase congestion at the center if they all intersect at a common point. It is therefore best to de-concentrate traffic as it approaches the center, by stopping the main thoroughfares a block or two short of actual intersection and con-

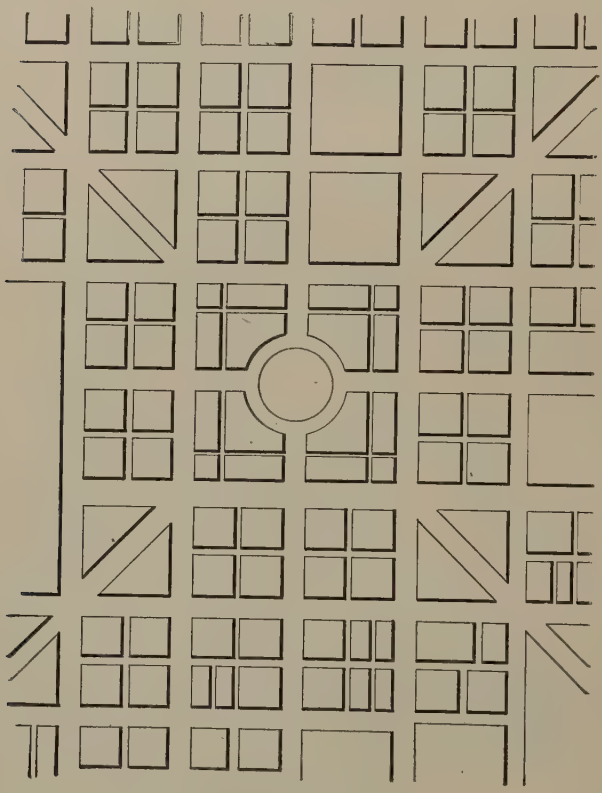


FIG. 7.—Center of Indianapolis, Ind.

Diagonals stop at square "ring street" which surrounds the business center.

necting them here by a ring street. (See map of Indianapolis center.) Moreover, much of the traffic will wish to pass *beyond* the center and not necessarily *to* it; and to avoid congestion at the center, thoroughfares should be provided giving convenient passage around it. In Detroit the congestion is diminished by

a combination of non-intersecting diagonals and partial ring streets. (See map, Fig. 8.)

Methods of de-concentration and by-passing the center are illustrated in Fig. 9. A bridge crosses the river at *a;* at *c* is the business center. At *k* is a manufacturing center receiving freight by river at the foot of the street opposite *k*, and by the railroad *al* at the freight station *l*. From *c* we have as radiating thoroughfares *ac*, *cd*, *ej*, *ci* and *bh;* while *agh* and *nb* divert the

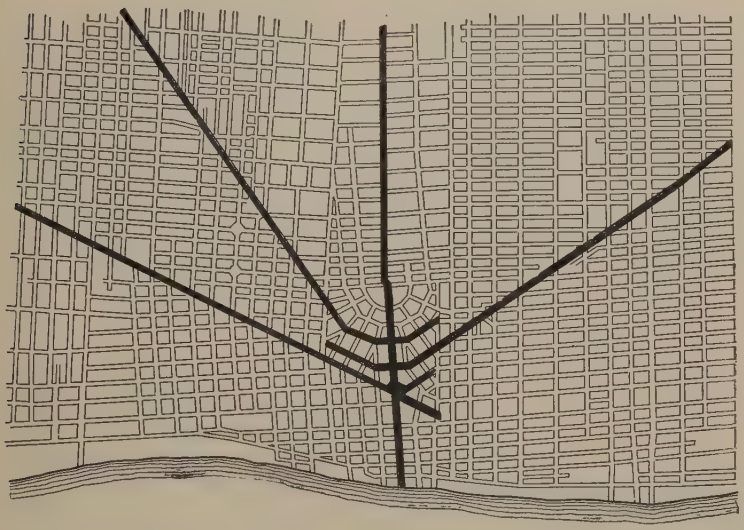


FIG. 8.—Center of Detroit, Mich.
Radial streets shown in heavy lines.

bridge traffic from the center to the right, and *am* connects the bridge with the manufacturing center and the freight yards near *l*. There is a ring street *defg* around the business center diverting from this to the right and left traffic passing from *B* or *C* to *A*, *I*, *D* or *H*. Communication between the radial thoroughfares and from sections *B* and *C* to the manufacturing center *k* and sections *F* and *G* is furnished by the cross thoroughfare *ijk;* while the thoroughfares leading up and to the left from *k* connect this center with the residence sections *E* and *F*.

As a city grows it may happen that the traffic using a given thoroughfare becomes so great as to unduly crowd it. This condition can be relieved either by widening this thoroughfare or providing others paralleling it. The former results in a wide, imposing street, but the multiple lines of traffic, if exceeding two in each direction, are apt to fail to keep separate and confusion and uneconomical use of the roadway width may result. If the roadway is very wide, therefore, it is generally desirable to

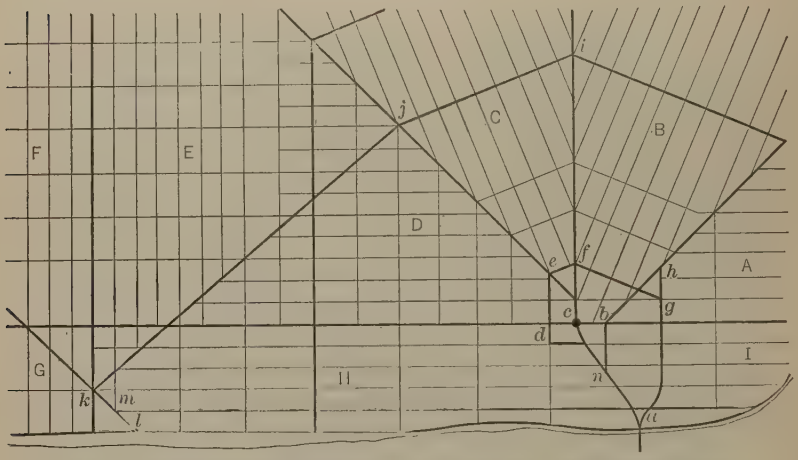


FIG. 9.—Radiating and Connecting Thoroughfares; Two Traffic Centers.

The main thoroughfares are shown in heavy lines. The light lines indicate minor and local streets, but no effort is made to place them systematically, or even to show all which might be planned.

introduce physical barriers dividing the roadway into separate strips for automobile, truck, railway, local service, etc. Such barriers may take the form of curbs or of narrow parkways. A disadvantage of the broad thoroughfare is that, in its early days, it is very much broader than is necessary and is extravagant of both area and cost of pavement or other treatment.

The providing of parallel thoroughfares, say one a block away on each side of the main thoroughfare, is preferable in that each of the three need then be made only a little wider than present conditions require, and the increase be provided for on the "elastic" principle (described further on); it shortens the route

to a greater number of users; one can be used for heavy trucking, another for touring cars, etc.; less inconvenience to traffic is caused by tearing up one at a time for repaving, laying under-

FIG. 10.—Street Railway Strip Separated from Roadway by Curb.

ground pipes, etc.; in the business district additional valuable frontage on thoroughfares is afforded; and it decreases the congestion of traffic at the center of the city.

FIG. 11.—Street Railway in Central Parkway.

The width required for final conditions and the full number of thoroughfares which are proposed should be provided in the original lay-out; but it is understood that only the width of roadway and number of thoroughfares required for immediate

use are at first paved and otherwise rendered suitable for such traffic, the width and number being increased as the traffic requires. This largely from motives of economy.

As to which system to adopt, the rectangular or radiating, the author believes that the only wise plan is to thoroughly appreciate the advantages of both, and use each where it best meets conditions and requirements. In most cities a combination of the two is best—radiating streets imposed on a generally rectangular system of thoroughfares. In general the business center (including an area sufficient to provide for future growth) should be laid out on the rectangular plan, this being most economical of building area and otherwise desirable for this district. (See Article 7.) From this area (from its outer streets, if not penetrating to its very center) diagonal thoroughfares should be drawn as the topography, existing roads or other conditions indicate. Secondary thoroughfares are desirable leading from each main thoroughfare, at intervals of a few blocks between city center and perimeter. These may consist of every third, fourth, or fifth street of the rectangular system, where these are already provided. They should be so located that no point within the city is more than 600 or at most 1000 feet from a main or secondary thoroughfare. It is commonly desirable to connect these secondary thoroughfares into a series of "ring streets" surrounding or partly surrounding the center of the city. Between these thoroughfares the areas may be laid out in various ways with minor or local streets, these forming rectangular systems in some cases, irregular in others.

The main thoroughfares will generally have a variety of directions, but those of minor and local streets can in most cases be fixed at the will of the designer. It is unfortunate that many of our cities have half the streets of their rectangular systems lying east and west, for buildings facing north and south never receive sunshine on their northern sides; the heat in such streets in summer is greater because there is little shade in the streets at any time, and there is always a glare in the eyes of pedestrians. It is desirable that no street be run making an

angle of less than 30° or 35° with a north and south line, so far as this is possible.

Special treatment of thoroughfares is often demanded by the topography, the most common controlling features being steep hills and valleys and bodies of water. In traversing steep slopes, thoroughfares should rise diagonally across contours, either in a continuous line or zig-zagging back and forth. The maximum grade permissible will vary with the locality. In most cases it should not exceed 3 per cent; but in cities where most streets are hilly and loads on vehicles are regulated accordingly, even 5 per cent or 6 per cent may be allowable. Frequently it is well to provide, in addition to light-grade thoroughfares, steeper and more direct routes for light vehicles and pedestrians, and occasionally narrow footpaths or flights of steps for the latter.

Several cities have solved the problem presented by steep, high hills by tunneling them, carrying a tunnel street from the foot of the hill to an outlet some distance back from the top of the slope, thus giving a light grade; or passing entirely through the hill on a comparatively level grade. (Pittsburg, Los Angeles, San Francisco, Chattanooga and Providence, R. I., furnish illustrations.) In other cases an aerial approach is made by an inclined viaduct from the crest of the hill to a point some distance from its foot. In a few cases both carriage and foot passengers are carried by large cable cars up very steep inclines; but this is both dangerous and more expensive in the long run.

Where a valley is the obstruction, a viaduct is the solution. These are sometimes made with roadways at two or more levels so as to connect several hillside streets by the one structure. Viaduct, cut or tunnel may be used to avoid a grade crossing of a railroad, the general topography and other conditions determining which is best. In general, a railroad embankment through a city is decidedly more objectionable than a railroad in cut.

Where practically all the traffic of a city must pass through one, two or three narrow valleys, the entrances to these become centers of radiation; and the thoroughfares through them should

be of ample width to provide for all future traffic, since parallel thoroughfares are impracticable.

Where a stream crosses the general direction of a considerable traffic, it is desirable that ultimately several bridges be available for such traffic. To secure this, diagonals should radiate from important traffic centers to each of several sites favorable for bridges. This is an important matter, and the locations of such sites should be carefully investigated. Width of stream and foundations for piers and abutments are among the important considerations. Unless such direct approaches be provided for each bridge, the one having the most direct ones is likely to remain congested, even though other bridges be built to relieve it.

Certain suggestions may be useful in designing a lay-out of main thoroughfares: A straight line on the plan is not necessarily the "shortest distance between two points" if time and energy required to go from one to the other be the measure; for a detour around a hill on a flat grade may be covered in less time and with larger loads than a straight course over it.

Diagonal short-cuts can often be used to advantage elsewhere than in reaching the business center.

Existing roads connecting the city with neighboring communities should in most cases be used, with or without modifications in alignment details, as a basis for the radiating system; that they already exist is a fairly safe indication that they have a reason for existing.

It is generally better not to join more than two main thoroughfares at one point, in order to prevent intense traffic congestion and confusion. (See Fig. 12.)

When two thoroughfares make an acute angle with each other, a short connecting street between them should be located about 200 or 300 feet from their intersection, to permit passing from one to the other without going around the acute angle, thus relieving congestion at that angle. (See Fig. 13.)

The greatest number of thoroughfares should be located leading in the direction of greatest traffic movement. If a city

lies between two large rivers or two lines of hills, for instance, few thoroughfares will be needed connecting these, but several paralleling them.

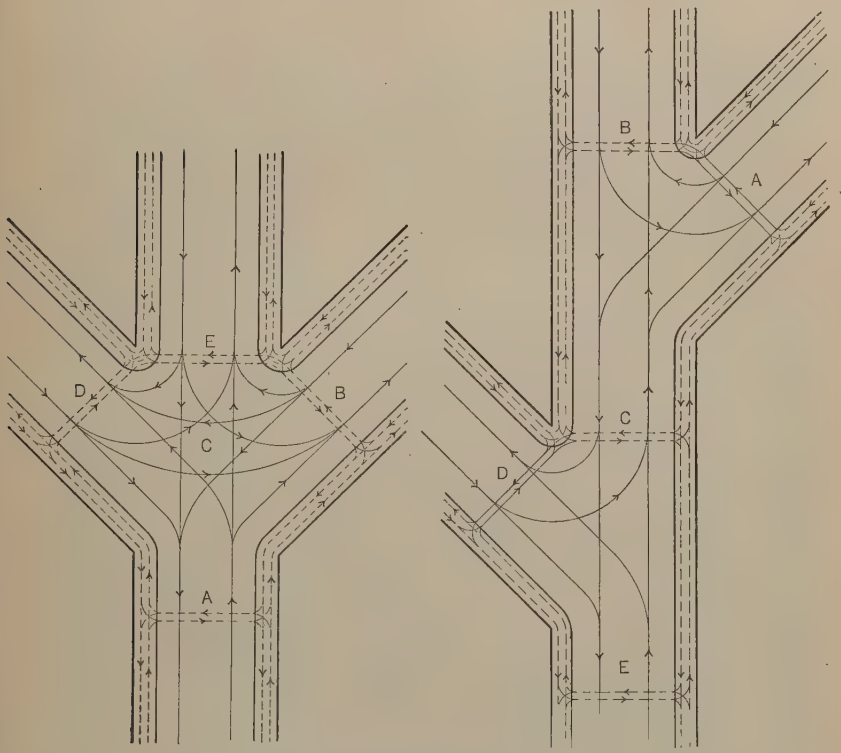


FIG. 12.—Opposite and Staggered Junctions.

Bringing two diagonal thoroughfares into a third opposite each other is not generally so desirable as to stagger the junctions, chiefly because the confusion of traffic is greater in the former. In the left-hand figure there are sixteen crossings of traffic routes (there may be two or more lines of traffic to each route) and eight points of junction of routes and eight of divergence. In the case of the staggered junctions there are six points of intersection, six of junction and six of divergence, and only half of the total number occur at one junction. The ultimate congestion is not diminished, but that at street intersections is.

The dotted lines show the pedestrian traffic. There is less danger to this in the case of the staggered than in the opposite junction. As a matter of fact, pedestrians would probably cut straight across the oblique junction, rather than at *A*, *B*, or *D*; and the danger because of this is a disadvantage of oblique junctions.

Curves should be made as flat as possible to reduce danger of collision of vehicles. Different authorities give from 300 to 1000 feet as minimum radius, but sharper curves are often required

in hill climbing. Double reversed curves, or "wiggles," are displeasing to the eye and present additional danger to traffic because of temptation to short-cut across them.

In the above, little has been said concerning pedestrian traffic, chiefly for the reasons that the same general rules apply

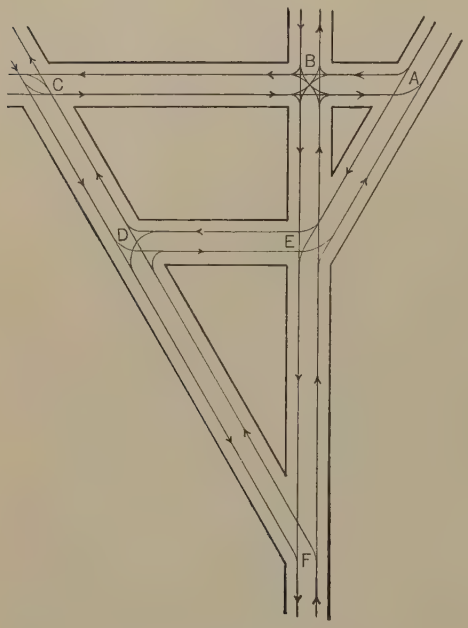


FIG. 13.—Cross-overs between Diagonals.

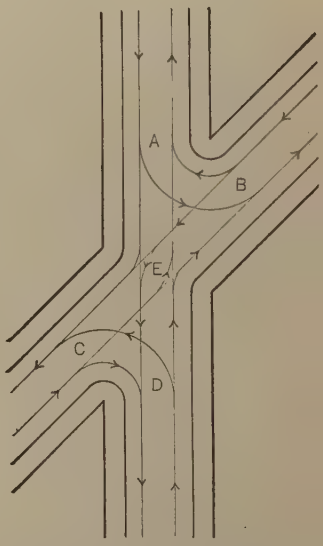


FIG. 14.—Continuous Oblique Crossing.

A part of the congestion at oblique junctions can be avoided by introducing cross-overs, as *BC* and *ED*, Fig. 13, to be used by traffic passing between streets *BF* and *CF*, which would otherwise turn around the corner at *F*.

Where a diagonal thoroughfare crosses rather than joins (Fig. 14), one street may be staggered or made discontinuous in alignment at this point; but this is less convenient for traffic on the discontinous street, and the total confusion and interference with traffic is probably increased rather than decreased.

to this as to vehicular, and that pedestrians seldom walk more than a half-mile continuously and that therefore most foot travel may be considered as local. There are some special cases, however, where a separate way may be provided for pedestrians alone. These take the form of short-cuts up steep hills by steps;

of narrow lanes; of foot bridges over streams, railroad tracks and other obstructions where heavier or more expensive bridges capable of carrying vehicles are impracticable or not worth the cost.

FIG. 15.—Steps up Hillside too Steep for Roadway. New York City.

Little has been said concerning the health, comfort, convenience or pleasure of the resident along thoroughfares because these must be subordinated to securing the routes which will most satisfactorily serve the people at large. Also these are more matters of width of street and size of block than of general lay-out, which features will be considered in the following articles.

The above has dealt chiefly with original designing of the streets of an entire city; but redesigning to correct past mistakes and the laying out of additions to the city are more common problems. The latter generally involves the continuing through the new area of one or two main thoroughfares, providing secondary thoroughfares branching from these at 600 to 1000-foot intervals and joining similar thoroughfares in the territory on all sides of it; and filling in the remaining area with minor and local streets. Due regard will of course be had to the pur-

Fig. 16.—Steps for Pedestrians; Roadway to the Left. Salt Lake City.

pose for which the area is to be used; and especially should a skeleton street plan be prepared more or less definitely for the territory for some distance beyond in all directions, in order that the present plan may not occasion difficulties in future planning which a little foresight could have avoided.

Replanning is probably rendered necessary more often by the absence of a main thoroughfare leading in a desired direction or by insufficient width than for any other reason. In some cases the demand can be met satisfactorily by introducing short connecting

links between discontinuous streets; by cutting off angles so as to make a continuous street of a series of short ones not in alignment, or by making other use of existing streets. In other cases an entirely new street must be cut out of blocks already built up.

While it is desirable that a main thoroughfare be laid out as direct as possible, a crooked one is better than none and may be justified on the score of economy of using existing streets. On the other hand, an entirely new street may often be so laid out as to wipe out eye-sores, fire-traps and other relics of an outgrown business infancy.

As already explained, it is better in most cases to start a diagonal from an existing main thoroughfare a block or two from

FIG. 17.—Footbridge Over and Driveway Across Tracks. Los Angeles.

rather than at the center, and not to begin two at the same point. This also will often reduce the cost of purchasing and removing buildings in the line of the proposed diagonal. Widening existing thoroughfares will be considered in another article.

Local Streets. In local streets the residents are the first consideration. Living conditions take precedence of traffic conditions. The citizens at large have no interests or rights there except to prevent the creation of nuisances or to secure conditions making for health and comfort of the residents which the latter individually have not the power or intelligence to secure.

There must be districts for the poor, the rich and the great middle class; for those who desire as much of the rural in their surroundings as can be had in a city, and for others in which the gregarious instinct is the ruling one. Moreover, a variety of treatments is necessary to prevent a depressing monotony in the city's appearance. For these reasons local streets will be straight, winding, broad, narrow, crowding upon or withdrawing from the thoroughfares. The designing of these is an art rather than a science, and books on city planning should be consulted

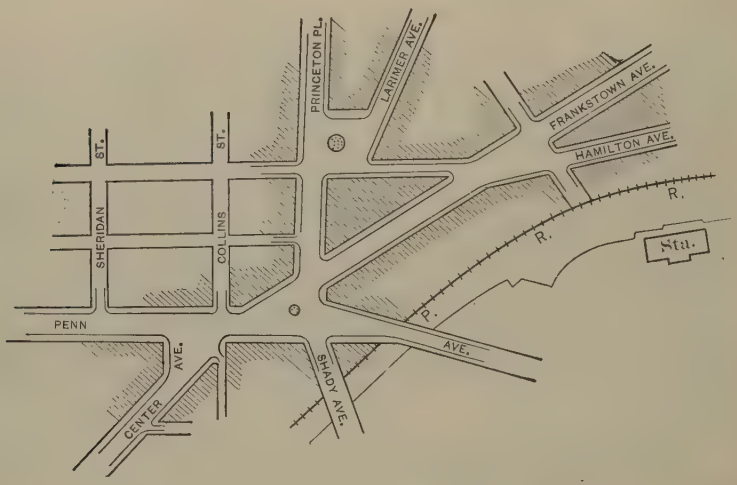


FIG. 18.—Streets Having Closed Views. Pittsburgh.

for hints on the subject. The following suggestions may be offered, however:

Winding streets are appropriate for hilly, irregular land and rural treatment (abundant trees, lawns, shubbery, etc.). Each turn should have a visible reason—to follow a contour or avoid an obstruction. Streets should not wiggle around aimlessly.

Local streets should discourage through traffic. Dead ends, numerous turns, occasional steep grades and other devices will assist in this.

French treatment, consisting of broad straight avenues with long vistas, is desired for pretentious dwellings; but this demand is generally met by the thoroughfares.

Long straight lines are not desirable in general, but there should be bends which will replace with trees and buildings the sky glare at the end of a long straight street, or at the top of hill. Several intersections to effect this are shown in Fig. 18.

The following rules were adopted by a commission appointed to prepare a street plan for the District of Columbia outside of Washington. They apply to all classes of streets in any country except a flat one:

"1. That avenues* should be extended with great directness to the District line, forming a fan-shaped system of highways to the city. This gives the essentials of a spider-web system.

"2. That on account of its simplicity the checker board or gridiron system should be located wherever maximum grades of 6 per cent shall not be frequent or cause cuts and fills to exceed 20 feet.

"3. That where direct extensions would be of undulating grade, curved highways are preferable, adding a picturesque feature to the system and relieving the monotony of straight lines.

"4. That curves of small radii should be avoided and in very broken sections of narrow ridges or valleys it is preferred to follow the sides rather than the top or bottom of the hill.

"5. That the largest number of avenues should lead to or from the city and cross avenues be infrequent and located on prominent ridges or on easy lines of communication.

"6. That small parks and circles which are such prominent features of the city plan be eliminated from the extended system and that large areas on prominent points of view be selected as parks and connected by avenues or curved drives."

It is generally desirable to locate a street in the bottom of a narrow valley carrying a small stream or storm run-off, as the

* "Avenues" is used to indicate what we have called main thoroughfares.

street can then carry in gutters or storm sewer the drainage water which would otherwise cross private land.

Alleys and Parks. Alleys are placed through the centers of blocks in many cities to provide out-of-sight places for collecting ashes, garbage, etc., for delivering milk, groceries, coal and the like, and to serve as locations for private stables, garages, etc. They also are useful in fighting fire, especially in congested districts, and increase the air and light spaces at the rears of buildings. In some cities water, gas and sewer mains are placed in the alleys, thus avoiding the digging up of the streets. To best accomplish their purpose of hiding the removal of offensive and unsightly matters, alleys should be continuous from block to block, and afford, as far as possible communication between each house and the point of disposal of these matters without the use of any streets. This is generally accomplished by running an alley through the center of each block parallel to the main thoroughfares; they should not *cross* thoroughfares any oftener than is necessary. If properly constructed and maintained, alleys are a great aid to the cleanliness and beauty of a city; but if paved poorly or not at all and allowed to accumulate ashes, garbage, manure, etc., they become intolerable nuisances vastly worse than the evils they are intended to prevent. The prohibiting of board or other solid fences along the sides of alleys, leaving them open to view from the buildings they serve, would probably do much to prevent their becoming such disgraceful nuisances.

Parks will be considered more in detail later; but are mentioned here as provision should be made for them in the street plan. It is claimed that not less than 5 per cent nor more than 10 per cent of the city's area should be devoted to small parks and squares. Often the land least desirable for building is most so for parks; such being gulleys, ponds, steep hillsides and small irregular areas formed by several streets intersecting. The banks of a stream offer a most favorable location for a park. The larger city parks generally consist of a regular city square or several such, or a part of one. The plan as a whole is therefore not affected by them.

Cemeteries are needed in or near every city, but every consideration dictates that they be located outside or just within the borders. They therefore ordinarily require no modification of the general plan and will be discussed further on.

A stream through a park or cemetery may be left as natural as possible, swampy spots being eliminated by filling in; but through the city proper a different treatment is desirable. The alignment should generally be straightened and frequently the course may be altered to prevent interference with streets or bring it into the line of one. (Methods of treatment are discussed in Article 15.) But the line should be decided upon at the time the street plan is prepared, to avoid future complications with either streets or buildings.

Art. 7. Sizes of Blocks

By size of block in this book is meant the dimensions between the property lines, and not between the center lines of streets.

The *general principles* involved are of two classes: those relating to the streets and those relating to the buildings. The former deal with convenience to the public at large in affording passage to and along thoroughfares, and to the local occupants in affording access to their residences or business places from the main thoroughfares. The latter deal with convenience and economy of arrangement of buildings and accessories, the lighting and ventilation of the same, provision for yards, freight sidings, etc. Thus different sections of a city will require different sizes of blocks. In the majority of cities most of the buildings face upon the main thoroughfares, and the greatest economy of space would result from the omission of all cross streets. These are necessary, however, for passing from one avenue to another; the more there is of such cross-travel in any given section the more frequent the cross streets should be. Another effect of the cross street is to afford access to more than one side of the corner buildings—desirable for mills, factories, office buildings, etc. In a mixed retail and residence district the residences preferably face upon the cross streets, which are less noisy and valuable, the business upon

the thoroughfares. In residence sections groceries, drug stores and other local trades seek corners as advantageous sites; and this and the desire of many residents for the additional light and air furnished by the cross-streets give corner properties higher values, which fact tends to partly offset the loss of available land occasioned by such streets.

The *distance between thoroughfares* will be twice the average depth of the lots facing thereon, plus the width of the alley, if any. The desirable depths of lots must be determined largely by judgment, assisted by statistics. Opinions given by city engineers or other officials of 47 cities in this country as to the most desirable dimensions for lots show the following extremes and averages: For depths of lots: Highest class residences, 120 to 400 ft., average 174 ft.; middle class residences, 100 to 200 ft., average 146 ft.; laboring class residences, 70 to 200 ft., average 131 ft.; business purposes, 100 to 200 ft., average 132 ft.

If 20 ft. alleys be located through the centers of all blocks, we have the following distances between thoroughfares, using the above averages: High class residence district 370 ft.; middle class residence 310 ft.; laboring district 280 ft.; business district 285 ft. In New York City above Tenth street the blocks are 200 ft. wide, without alleys. In Troy, N. Y., the width is the same. In a plan for a manufacturing district on Newark Meadows, James Owen designed blocks 325 ft. wide. The author suggests as general average dimensions, exclusive of alleys: Good class of residences, 250 to 300 ft.; laborers, cottages, 175 to 250 ft.; business, 150 to 200 ft.; manufacturing, 200 to 350 ft.

The principle that the greater the traffic in any direction, then more the thoroughfares which should be provided leading in that direction, calls for the longer dimensions of the blocks to be along such thoroughfares and the shorter dimension to be that between thoroughfares. The violation of this was a serious mistake in planning the streets of Manhattan Borough, New York.

The *lengths of blocks* are generally of less importance than their widths, and show great variation in different cities. In Salt Lake City all blocks were made square, 660 ft. on a side, which

has proved to be too much considered as width, and many of them have been bisected by passing an alley through them. In New York's rectangular system the blocks are 420 to 920 ft. long; in Troy 350 to 700 ft. In Denver the prevailing length is about 500 ft.; in Philadelphia 300 to 500 ft.; in San Francisco 375 to 800 ft. The following are suggested as average lengths: residence districts, 400 to 700 ft.; business, 250 to 350 ft.; manufacturing, 500 to 1000 ft. The short business blocks are to permit general intercommunication; the long manufacturing ones, to allow of large mills or factories.

The value of land for residential purposes increases directly as the frontage but not in proportion to the depth of lots; but too great shallowness of lots may prevent sale of the lots advantageously. The desirable depth will depend to a certain degree on local custom. It may also depend upon the street width; where streets are narrow the residences should set well back from the street line, thus reducing the size of the back yard, which should be compensated by depth of lot. In general it may be said that the above suggested widths of blocks assume street widths of 60 to 80 ft. If the widths of streets are less, the widths of blocks should be correspondingly greater.

Art. 8. Widths of Streets

The functions of streets, as previously stated, are threefold: to act as thoroughfares, as means of access to property fronting on them, and as open spaces for admission of light and air to buildings. The first named function does not apply to local streets, but the other two apply to all. Thoroughfares require a width sufficient to allow to pass through them without danger all the numbers and characters of vehicles for which they are the natural routes, together with all the foot passengers desiring to do so; at the same time allowing room for vehicles to stand at the allotted places, and for pedestrians to stand close to show-windows, etc. Minor streets should meet the same requirements, but the numbers to be provided for are very much less. These two functions apply to the street surface only. To admit light

and air, the width between buildings must be ample from ground to roofs. Another function is assigned to modern streets—to contain beneath their surfaces pipes, wires, conduits and numberless other contrivances both public and private, and to carry the same above their surfaces also. The first three are the proper functions of streets and in no way interfere with each other; the last named interferes with each of the three proper functions, and it would be desirable that a separate space be assigned for these, either interposed longitudinally in the street or placed entirely without its limits, but for considerations of economy.

As a passageway for vehicles, the street is limited between curbs (or curb lines); for pedestrians it is limited between curb and property or fence lines; for admission of light and air its width extends between buildings at their roofs, which may be greater than that between building lines or even between the buildings at the ground level.

Sidewalks are intended for pedestrians only, for whose safety and convenience all other modes of locomotion are forbidden thereon. To insure against encroachment of vehicles and of drainage water, curbs may be placed between the sidewalk and roadway. To keep the sidewalks dry, they are given a slight slope toward the gutter. Their width should be sufficient between curb and building line to permit the greatest ordinary number of pedestrians to pass going in opposite directions without undue crowding. On a local street, where there is almost no travel, 5 ft. is sufficient width, and $4\frac{1}{2}$ ft. is adopted in some cities, as this permits two persons to pass each other or to walk abreast. For a street with a small amount of through travel there should be room for four people abreast, or about 10 ft. For retail business, the width should be from 15 to 30 ft., depending upon the size of the city. The above dimensions refer to available passageway, properly paved. The New York rule for distance between curb and building line is:

Width of street	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	80 to 100 ft.	over 100 ft.
Width of sidewalk	10 ft.	13 ft.	15 ft.	18 ft.	19 ft.	20	22
Width of roadway	20 ft.	24 ft.	30 ft.	34 ft.	42 ft.	43 to 60	over 60 ft.

There are many exceptions to this. The sidewalk of Grand Boulevard is 24 ft.; of Central Park West 25 ft., East 27 ft.; of West End avenue 30 ft.; of 5th avenue 30 ft.; of north Lenox and 7th avenues, 35 ft. Frederick Law Olmsted, in a report on main thoroughfares for Pittsburgh, gives 18 ft. as a "satisfactory minimum" for a sidewalk on an ordinary main traffic street. In estimating, allowance should be made for projections of store windows, steps, etc., allowed by ordinance (say 18 to 24 inches); also for fire hydrants and posts along the curb line.

In certain cases the sidewalk space may be narrow or even entirely omitted, as in front of warehouses, wholesale storehouses and the like, where there is practically no through foot traffic on the entire block, and heavy carts and drays back up to the buildings; also along railroad yards, wharves, etc. Also on hillside streets one sidewalk may be omitted; which, with other special treatments, will be considered later.

A common rule in many cities, which seems to be fairly satisfactory, is to make each sidewalk one-fifth of the street width (one-third of the roadway). Table XIV gives the average widths of sidewalks in a number of cities. In general two and a half to three feet of width and five to six feet in length should be allowed per person using the sidewalk, and a speed to two to three miles per hour. How to estimate the number of pedestrians to be allowed for is something no one has yet discovered. Where there are large office buildings or factories, however, the sidewalk widths in our older cities have proved too small; the entire sidewalk and roadway of some of New York's streets being congested when the occupants of tall abutting office buildings are entering or leaving, as at noon hour. For such districts 25 or 30 ft. is none too wide for sidewalks.

The width between building lines should be the greatest which will probably be required for a century or more, since the cost of moving the building lines further back after the city is built up will be enormous. The paved walk, however, need be no wider at any given time than necessary to meet the demands of that time. For side streets, 10 to 15 ft. will probably

Table XIV

WIDTH OF CITY STREETS—(From Byrne's "Highway Construction.")

City of	Width of Streets Between Building Lines		Maximum Grade. Feet Per 100 Feet	Average Width of Sidewalks. Feet
	Maximum Feet	Minimum Feet		
New York, N. Y.	100	60	13	15
Brooklyn, N. Y.	100	60	12	18
Buffalo, N. Y.	100	40	7	23
Syracuse, N. Y.	120	33	20	
Elmira, N. Y.	100	33	5	14
Schenectady, N. Y.	90	20	8	
Boston, Mass.	.....	.....	.....	7
Lynn, Mass.	100	50	17.21	8
Worcester, Mass.	100	20	20	17
Lowell, Mass.	70	30	16	14
Cambridge, Mass.	102	26	11.66	8
Chicago, Ill.	150	30	2.40	25 to 4
Bloomington, Ill.	100	30	4.80	
Jersey City, N. J.	80	30	14	
Camden, N. J.	100	26	3	15
Newark, N. J.	132	40	10	10
Trenton, N. J.	80	30	8	16 to 6
Paterson, N. J.	120	40	17	
Terre Haute, Ind.	99	50	5	
Richmond, Va.	118	30	3	
Omaha, Neb.	120	40	15	13
Nashville, Tenn.	104	20	11	17
Parkersburg, W. Va.	60	40		
Washington, D. C.	160	80		
Wilmington, N. C.	99	30	9	17
Seattle, Wash.	120	60	.....	16 to 8
Philadelphia, Pa.	120	30	16	
Pittsburgh, Pa.	100	30	15½	⅔ width of street
Erie, Pa.	100	50	.....	20 to 12
Harrisburg, Pa.	120	20	7	⅓ width of street
Providence, R. I.	225	10	19	⅓ width of street
Cumberland, Md.	65	20	10	
Hartford, Conn.	70	25	6	6 to 4
Waterbury, Conn.	160	28	13	6
New Haven, Conn.	100	40	12	20 to 8
Detroit, Mich.	120	36	5	20 to 6
Grand Rapids, Mich.	100	50	12	12 to 4
St. Paul, Minn.	200	50		
Minneapolis, Minn.	120	60	.....	27
Bucyrus, O.	88½	40	.....	16
Salt Lake City, Utah	132	50	15	20 to 6
Ogden, Utah	132	60	12.38	16 to 10
Burlington, Vt.	99	28	10.70	
Rutland, Vt.	99	49½	10	12 to 6
Milwaukee, Wis.	100	60	9	25 to 12
*London, Eng.	80	12	4	15 to 3
*Birmingham, Eng.	80	15	9	8

* Foreign cities for comparison.

TOTAL WIDTHS OF FOREIGN STREETS.

Berlin:	Unter den Linden (includes broad walk with two rows of trees)	196 ft.
	Leipziger Strasse and Friedrich Strasse	72 ft.
	König Strasse	57 ft.
Brussels:	Boulevard Circulaire	220 ft.
	L'Avenue Louise	183 ft.
	Avenue Midi	118 ft.
Paris:	Avenue Bois de Boulogne	393 ft.
	Avenue des Champs Elysées	229 ft.
	Avenue de l'Opera	98 ft.
	Rue de Rivoli	88 ft.

be always ample; for purely residence thoroughfares, the same; for local residence streets 5 ft. is customary; for business thoroughfares, 20 to 35 ft. should be allowed; for business side streets in the heart of the retail district, 20 to 25 ft.; for streets in wholesale districts 15 to 20 ft. will generally be ample.

A roadway should be sufficiently wide for the greatest number of lines of vehicles which will be entitled to and wish to use it at any period of its existence; not, however, for as many as may wish occasionally at some moment to crowd by one another. The size and character of vehicle which may use a given street may be regulated by city ordinance. Local streets should not be used as thoroughfares; and trucking may be excluded from some streets, automobiles from others and street railways from still others.

A local residence street need provide for only two vehicles of ordinary size to pass each other. Coal carts, moving vans and limousines will probably be the largest vehicles to use the street. The traffic will be so infrequent that a little maneuvering occasionally to effect a passage is no hardship. If the street is a dead end, there should be room at the end ample for any of these to turn around in. (Fig. 19. Frontispiece.)

At the other extreme is the main thoroughfare in the heart of the city, or the main pleasure boulevard. The former will need to contain two street car tracks, a more or less continuous line of vehicles drawn up along the curb, and at least two lines of vehicles between these and the railway strip on each side of the street.

The pleasure boulevard will generally require to accommodate about the same number of lines of vehicles, but some moving more swiftly than in the business district and therefore with more clearance to avoid collisions.

The width of vehicles varies. From $6\frac{1}{2}$ to 8 ft., hub to hub, would include most vehicles, except motor trucks, which may reach even 9 ft. It is not believed by most motor manufacturers that this width will be exceeded in the near future. If a vehicle is drawn close to the curb, six inches additional for clearance is

FIG. 20.—Six Lines of Vehicles, Two Using Car Tracks.

sufficient; but for moving vehicles a foot clearance should be allowed as a minimum for each, and 2 ft. on boulevards. General practice varies between 8 and 9 ft. as the allowance per vehicle. Street cars on two tracks occupy about 17 ft. 6 in. to 18 ft., and 20 ft. should be allowed to provide clearance; or 10 ft. for a single track. Where cars run infrequently (say once in five or ten minutes) and traffic can be accommodated by one line of vehicles in each direction; if there are varying speeds, the faster vehicles can use the track space for turning out. But this should not be required if greater width can be obtained.

Using these figures, we have 18 ft. for the roadway of a local residence street. For the main thoroughfare we have 9 ft. for each line of standing vehicles and for each of four lines of moving vehicles, and 20 ft. for the railway strip, a total of 74 ft. For the boulevard roadway, with six lines of vehicles and 2 ft. clearance, and allowing 8 ft. for limousines, we have 60 ft., with 20 ft. added if there is a double track railway, or practically the same as the main thoroughfare. (In practice, parking strips, bridle paths, etc., may increase this.)

In the case of the wholesale warehouse street we must provide for trucks backing up to the buildings on each side. If there is a sidewalk, this will probably be used as a part of the roadway so far as this use is concerned, and the width calculated will be from building to building. There must be room for at least one—preferably two—lines of moving vehicles between two opposite lines standing backed to the buildings. Trucks generally run from 17 to 20 ft. long. Given trucks 20 ft. long and 9 ft. wide, this calls for a total width of 60 ft. between buildings. If sidewalks can not be used by vehicles but must be bridged temporarily from truck to building (the truck will overhang the curb 3 or 4 ft.), 10 or 12 ft. must be added to this. A good plan (seldom used, however) is to place the sidewalk of such a street in its center line.

In the secondary business street we must provide for standing vehicles, but only three lines of moving vehicles and no car

FIG. 21.—Warehouse Street with Loading Platforms. Sidewalk Almost Useless.

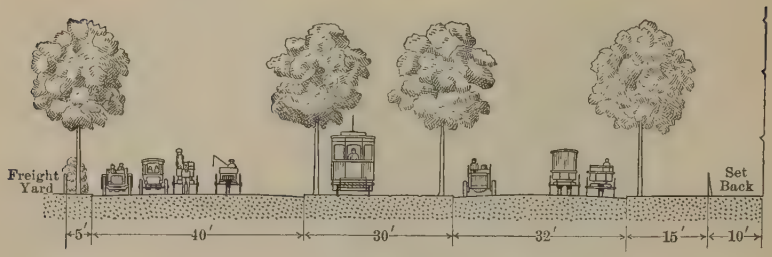
tracks may generally be assumed (or a single car track used as a turning-out space)—a total of 45 ft. between curbs.

The same principles may be employed in calculating roadway width for any class of street. Consideration should also be given to other conditions or possible uses. Thus, a coal cart backing up to a curb will occupy 12 to 14 ft. of roadway, requiring 20 to 22 ft. width to permit another team to pass, and this is perhaps preferable to 18 ft. for a residence street where the conditions are such that the coal can be delivered directly by chute to the coal hole.

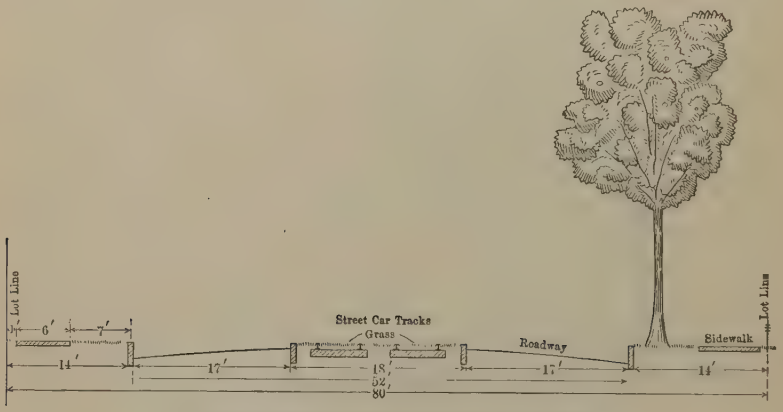
The above are given as the *minimum* distances *desirable*. Less widths are found in many cities, but are a handicap to its street traffic and add to the cost of distributing merchandise. Greater widths, on the other hand, add to the cost of paving construction and maintenance and decrease the building area available, and thus indirectly cause increased rents. It should not be forgotten that the street should be so designed as to provide for the traffic of years (fifty or one hundred at least) in the future.

Other traffic strips are sometimes provided for bicycle paths (these are less common now than ten or twenty years ago), bridle paths in boulevards and streets connecting a system of parks, speedways, and lanes. For bicycle paths $5\frac{1}{2}$ ft. (as in Portland, Ore.) or 6 ft. (as in Babylon, L. I.) in the clear is necessary, unless it is possible to turn out from path to roadway and back again, when 3 to 5 ft. is sufficient. For a bridle path 8 to 10 ft. is desirable. For a speedway not less than 40 ft. is necessary, and 75 ft. is more commonly allotted. (Harlem river, New York, speedway has a 95 ft. roadway, a 10 ft. parkway on each side, and one 20 ft. and one 15 ft. sidewalk beyond these.)

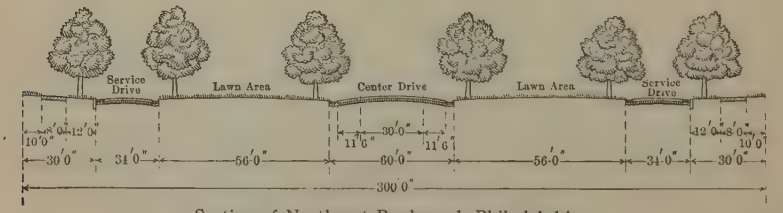
Alleys should discourage use for any purpose except delivering goods and removing ashes, garbage, etc., as entrances to private stables or garages, and for fire fighting. No sidewalks are necessary, and 10om for two teams to pass is sufficient; in fact, alleys may be confined to "one way" traffic and allow room for



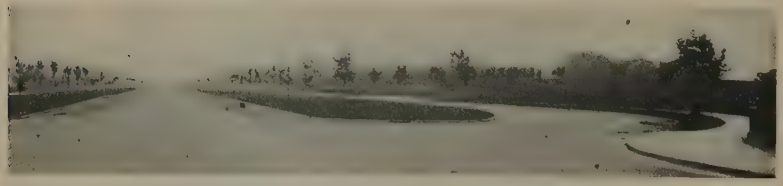
Boulevard along Freight Yard. Buildings and Sidewalks along One Side Only.



80-Foot Residence Street with Street-car Tracks.



Section of Northeast Boulevard, Philadelphia.



View of Northeast Boulevard, Philadelphia.

FIG. 22.—Typical Sections of Wide Streets.

one wagon only. Therefore 10 to 20 ft. is ample, and more is inadvisable.

Lanes are for pedestrian use only, and are generally short-cuts or intermediate passages in the middle of long blocks. They could be used to advantage more frequently than they are. Five to 8 ft. is generally sufficient width to allow in residence districts, this including overhang of hedges at the sides. In the business district they may be 20 or even 25 ft. wide. To prevent vehicles entering them, a row of posts may be set across each end, where they are not protected by the sidewalk curb.

Parking or planting strips containing sod, trees, shrubbery, etc., are common in residence and even in some business streets. They are less expensive than roadway or sidewalk paving; serve to separate the two, thus adding to the safety of pedestrians and reducing the dust and splashing of water which might reach them from the roadway; add greatly to the appearance of the street; and the trees furnish shade, thus adding to the health and comfort of both traffic and abutting owners. They also permit considerable variations in level of roadway and sidewalk and other adjustment of street details which might be difficult otherwise. Shrubbery may occupy a strip 3 to 5 ft. wide. Trees should have 5 ft. at the least, and 6 or 7 ft. is preferable. (Where the sidewalk pavement extends to the curb, trees should have around the trunk an unpaved area leaving at least 18 in. opening on every side of the trunk after the tree has obtained its growth). Sod may of course be of any width; but if less than 5 or 6 ft., it is more apt to be left uncut and neglected; and if there is no curb, the drop from pavement to gutter may be too steep. In general 6 to 20 ft. is desirable for a parked strip next to the roadway. For one next to an unfenced lawn, any width may be used, as it is practically only an extension of the lawn.

Parkways are wider planted strips, often with a foot path through their center. They generally contain two or more rows of trees or a series of formal gardens, and are set off from the roadway by curbs. In most cases a long continuous parkway

(with breaks for cross streets) occupies the center of a wide street, with a roadway on each side. What are in a sense parkways are provided in boulevards of several cities as location for street railway tracks, the strip occupied by the tracks being sodded and set off from the roadway on either side by curbs, and occasionally by tall shubbery to reduce noise and dust.

FIG. 23.—Parkway in Middle of Narrow Residence Street, Pontiac, Mich.

The total width of a street is composed of the sum of such numbers and widths of the preceding as seem desirable. But this width should be decided not by the requirements of traffic alone, but by those of the comfort, pleasure and health of both those passing through and those living along the street. In general, in a thoroughfare the traffic requirements will provide ample width for these. But a residence street only 18 to 24 ft. between houses would meet the requirements of neither comfort nor pleasure. Light and air for the dwellings and the general appearance of the street demand greater width; how much more is a matter of judgment.

It is apparent that the height of buildings has a bearing on the amount of light reaching those opposite, and many cities have adopted rules based upon this idea. In several German cities the buildings on a street can not exceed in height $1\frac{1}{4}$ or $1\frac{1}{2}$ times the street width. In Boston, Charleston, Cleveland, Erie,

Fort Wayne, New Orleans and Youngstown the multiple is $2\frac{1}{2}$. Boston, Cleveland and New Orleans include the set-back as part of the width of the street. On residential streets in Washington, D. C., more than 70 ft. wide, the height must not exceed the street width less 10 ft. In cities of the second class in New York state, no residence may exceed in height the street width. Other cities limit the height by an imaginary line drawn from the opposite street line or the street center and making a given angle with the horizontal.

As the average residence seldom exceeds 45 ft. in height (at the eaves), the New York rule would give us a maximum of 45 ft. for residence streets. If the set-back (distance the building is back of the street line) is included, even less might be used for the street proper. A roadway 20 ft. and two 5 ft. sidewalks, giving a total of 30 ft., is probably a minimum for any street, and few would advise so narrow a street for this country. Roadway 22 ft., two 7 ft. planting strips, two 5 ft. sidewalks and two 2 ft. outside planting strips, giving 50 ft. width, is a good combination; but it would be desirable to have a building line established at least 5 or 10 ft. back of the street line, or if this set-back is not assured, to add 5 ft. or more to each outside planting strip, keeping the sidewalk pavement 7 to 12 ft. from the buildings. (Omission of the planting strip next to the curb will be considered later.)

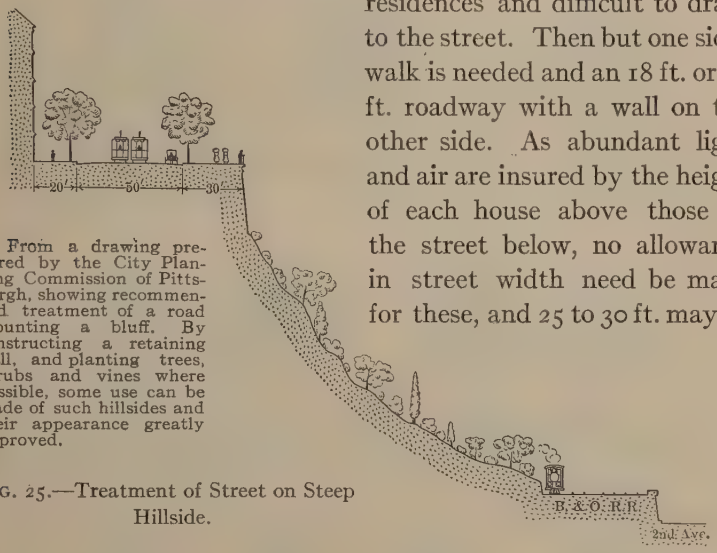
The width of business streets and thoroughfares will generally be the sum of the roadway and two sidewalks, having widths fixed as before described. Planting strips in a business district interfere with the full use of the sidewalk, access from store to wagon or carriage, or from sidewalk to sidewalk. Trees, however, may be planted without any more allowance in sidewalk width than for posts.

Pleasure boulevards may be of any width which the city is willing to maintain—a combination of roadways, sidewalks, parkways, planting strips, bridle paths, bicycle paths, street railway strips, speedways—generally two to four roadways and sidewalks and the others as desired. But the cost of caring for

FIG. 24.—Main Traffic Roadway with Side Service Roadways.

these is considerable, and unless well kept up they are liable to fall into a condition disgraceful to the city.

Special conditions may call for special treatment. Streets on steep hillsides approximately following the contours may well be placed only say 100 ft. apart, with houses on the up-hill side only, since the lots on the other side are undesirable for residences and difficult to drain to the street. Then but one sidewalk is needed and an 18 ft. or 20 ft. roadway with a wall on the other side. As abundant light and air are insured by the height of each house above those in the street below, no allowance in street width need be made for these, and 25 to 30 ft. may be ample width for the street. If the hill is so steep that no building is possible until near the top, however, an outer sidewalk may be desirable on account of the view, the hill below being planted. (See illustration.)



From a drawing prepared by the City Planning Commission of Pittsburgh, showing recommended treatment of a road mounting a bluff. By constructing a retaining wall, and planting trees, shrubs and vines where possible, some use can be made of such hillsides and their appearance greatly improved.

FIG. 25.—Treatment of Street on Steep Hillside.

The following are average widths found satisfactory under ordinary conditions:

For boulevards or thoroughfares with parkways 150 to 300 ft.

For water front streets and other localities where freight is handled 100 to 250 ft.

For diagonal thoroughfares 100 to 150 ft.

For business thoroughfares 100 to 150 ft.

For pleasure boulevards without parkways 75 to 150 ft.

For pleasure boulevards with parkways 150 to 500 ft.

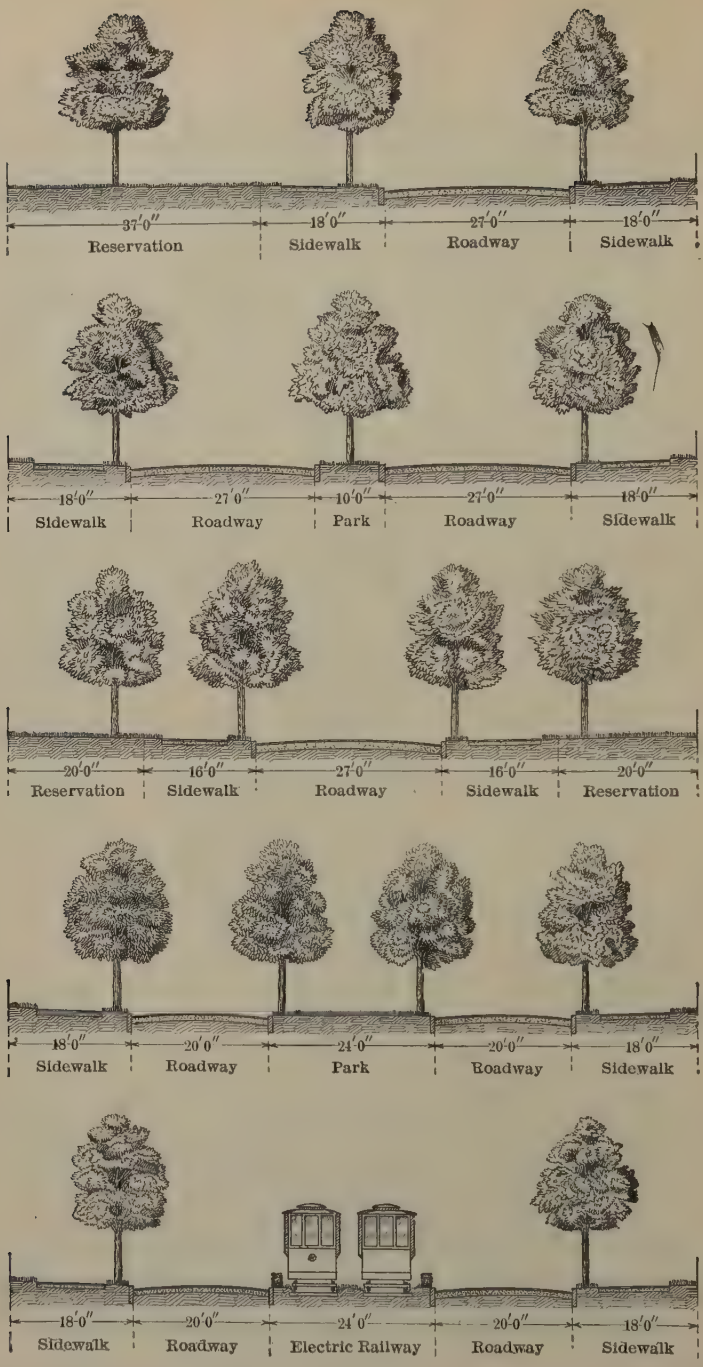


FIG. 26.—Various Treatments of a 100-foot Street. Suggestions of Philadelphia Bureau of Surveys.

For business local streets 80 to 100 ft.
For residence thoroughfares 80 to 100 ft.
For residence local streets 50 to 80 ft.
For wholesale and warehouse local streets 60 to 80 ft.
For alleys 10 to 20 ft.
For residence lanes 5 to 10 ft.
For business lanes or "courts" 10 to 25 ft.

"Elastic" Streets. A street which may some day be used as a main thoroughfare, but is now a minor thoroughfare or a

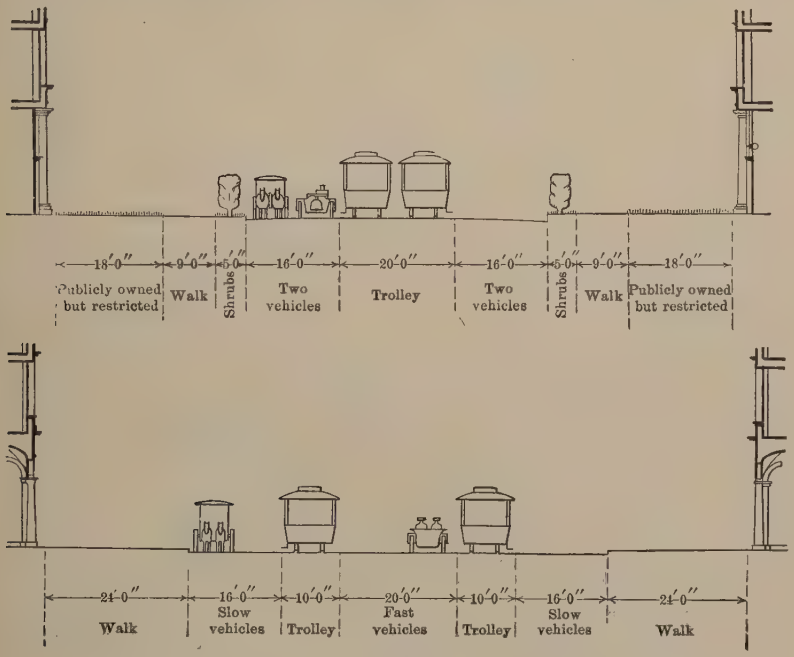
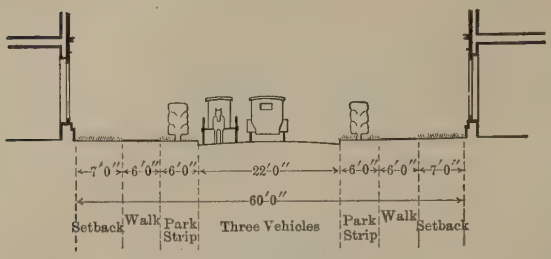


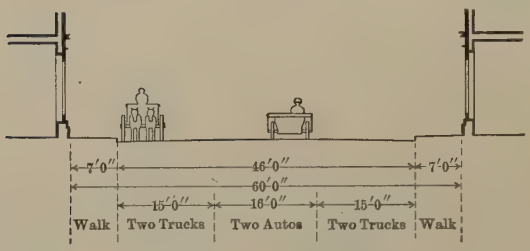
FIG. 27.—"Elastic" Main Thoroughfare; Initial and Final Stage.

residence street only, should have the width between buildings requisite for a main thoroughfare.

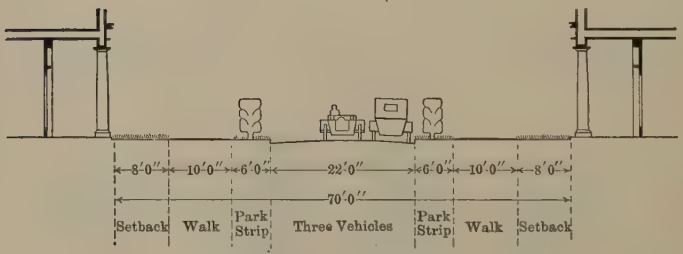
Preferably the city should own this entire width from the outset. Some state laws and city charters provide, however, that the city may prescribe a building line for any given street beyond which it is illegal for any building to be constructed, al-



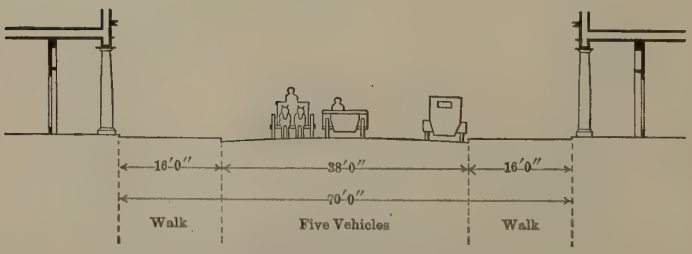
INDUSTRIAL, INITIAL STAGE



INDUSTRIAL, FINAL STAGE



COMMERCIAL, INITIAL STAGE



COMMERCIAL, FINAL STAGE

FIG. 28.—Elastic Streets, Industrial and Commercial.

though the city may not immediately possess as public property the entire width to this line. This permits the acquiring by the city at any time of the increased width necessary for increased traffic demands, without the necessity for purchasing or moving buildings.

In the immediate laying out of such a street, roadway and sidewalk widths are adapted to the present conditions on the principles already discussed. What is done with the remainder of the width must be determined by individual judgment and local conditions, topographical and otherwise. The superfluous widths may be concentrated on one or both sides of the street, becoming in effect extensions of the private property; or they may be distributed in the cross-

FIG. 29.—Elastic Street. Wide Parkway in Initial Form Draining Toward Final Location of Curb, *A*, Giving Minimum Change of Surface when Roadway is Widened.

AA are final location of curb and gutter, and planting strips *AC* drain toward these, as well as the sidewalks. *CC* are the initial locations of the curbs and gutters. The storm-water inlets may be placed in their permanent locations, as at the left; or in their temporary locations, as at the right. The dotted line indicates the final surface of the roadway in this and in the other sections of elastic streets.

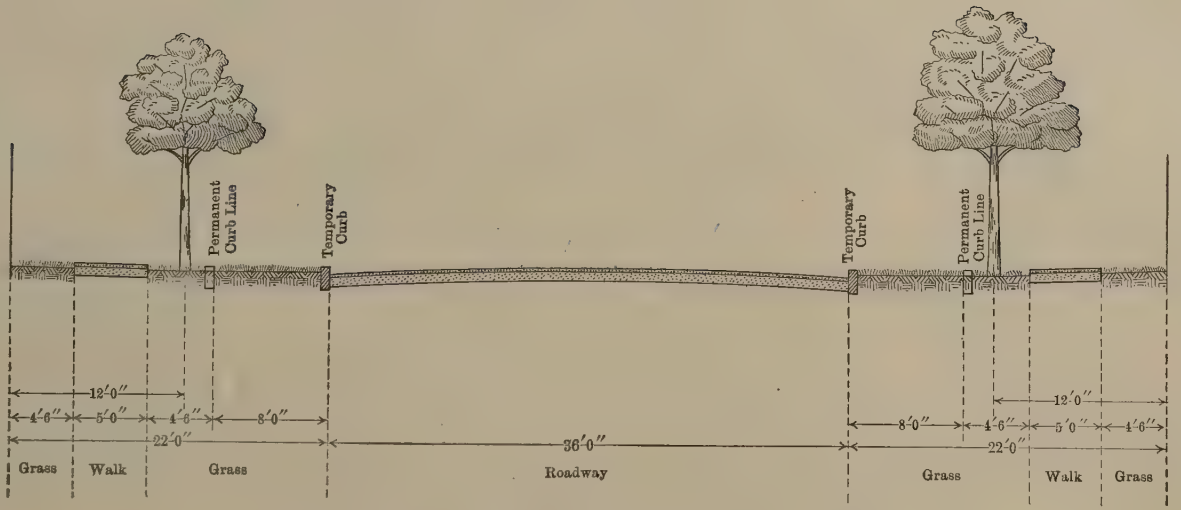


FIG. 30.—Elastic Street, Showing Initial and Final Location of Curb.

In this suggested section, slightly different widths are used. The total width is 10 feet less than in Fig. 29, but the temporary roadway width is 6 feet greater. The entire planting strip slopes toward the temporary gutter.

section of the roadway as planting strips or narrow parkways, located in the middle of the street or on one or both sides of each of the two sidewalks. Streets so designed for future widening are termed "elastic" streets. Where it is practicable (as it very frequently is), it makes for economy to so plant shade trees that they can be used not only in the present but also in the ultimate street plan; to establish grades of roadway or sidewalk or both so that little alteration will be necessary; to locate catch-basins and other structures, both surface and underground, so that they will not need to be changed with the widening. This is especially desirable in the case of trees, which it is impracticable to replace full grown in new positions when the street is widened.

Anticipating future conditions in this way necessitates planning the future as well as the immediate cross-section of the roadway, and locating trees so that they will be retained and occupy a desirable position in the final plan. Other trees may be planted also, to be removed when the street is widened, but not unless the temporary plan will probably continue for a number of years. The grades of temporary and final plans should be so designed that at the location of the trees there will be no change in elevation of surface. This is also desirable in the roadway as far as possible. There is an advantage, however, in raising the surface of the new roadway 3 or 4 in. above the surface of the old. In case the latter is to be a macadam road, it will probably have worn down 2 or 3 in., and a brick or other block pavement can be placed upon it as a base without disturbing it; or whatever the pavement, a new surface can be placed upon the old, either directly or after increasing the thickness of foundation.

The adapting of elastic streets to present requirements may effect very considerable saving in the cost of paving and that of cleaning and otherwise maintaining the pavement, and the other arguments against wide roadways already referred to apply also. Much more important is the providing of sufficient width for future requirements. Many of our older cities have spent

millions of dollars in condemning or otherwise purchasing private property, destroying buildings, etc., in order to secure width absolutely demanded by growth in traffic requirements.

Widths between Building Lines. In the case of local residence streets, in addition to width demanded by traffic, the matter of open spaces around the houses is important as it affects health and pleasure of the occupants. It is customary for cities to limit the area of building to some percentage (65 to 90 per cent in different cities) of the lot; but if the streets are to be designed by the private owners of the property being subdivided, a better plan is to fix a percentage of the total area, from street center to street center, which can be built upon. It would be well also to limit the height of building, or the cubic contents of all buildings relative to the total area.

The streets of most cities occupy 25 per cent to 50 per cent of the entire area of the city, and if 65 per cent of the remaining space be built upon, the built-over area amounts to from 39 per cent to 49 per cent of the total area. Considering a block 150×500 ft. bounded by 50-ft. streets and containing houses averaging 25×40 ft. in plan, 39 per cent would permit 42 houses on the block, or one for each 24 ft. front. In other words, building solid rows of houses 40 ft. deep on lots 75 ft. deep, the houses occupying 39 per cent of the total area, would give 50-ft. streets. This should be a maximum density for residence areas; and occupying 25 per cent of the total area by buildings would be desirable as a maximum limit set by ordinance in the sub-division of private property for residences in outlying districts. In laying out such a district on this principle, therefore, we may decide the average size of house which will be built upon the property and the widths of lots, and from this calculate the minimum average depth of lot measured from center of street to rear line of lot. Double this will give an average distance apart of street center lines. The layout of street center lines having been designed, the width of sidewalk and roadway may be fixed according to the ideas of the designer or property owner, limited by ordinance requirements. Among the latter it is

very desirable to specify the minimum distance each building must be placed from the center line of the street; which distance may be given as the height of the building eaves above the roadway level, with a minimum of 30 ft.; or different standard distances for different kinds of buildings, etc. Exceptional cases would be made of one-sided streets on hillsides, opposite parks and other open spaces, etc.

It is most desirable, especially for residence streets and streets on hilly or uneven ground, that the street be laid out approximately on the ground before the plan is finally adopted, and that this layout be studied with attention to the considerations already stated, and also to grade as it affects traffic and economy of street construction and of property grading. Of course, a contour map of the property will have been prepared before any planning is begun, unless the land is all practically level.

Art. 9. The Street Cross-Section

A large proportion of streets consist of a sidewalk space (with or without planting strip), and gutter (with or without curb) toward which the sidewalk slopes, on each side of a roadway which is crowned in the center. But, as previously stated, there may be only one sidewalk or none at all, or there may be no roadway, or the roadway may be dished rather than crowned, or may slope toward one side gutter only. The sidewalk may be level with, above or below the roadway, and the latter may be divided into two levels. These features of the cross-section design will be discussed in this article. The grade of the street and its plan and profile at street intersections will be considered under the head of grade (Article 10); and finally there are numerous details, such as isles of safety, monuments and other occasional features to be considered.

The sidewalk will always slope away from the house to carry the surface water in that direction. If of very smooth and plane surface, such as concrete or sawed stone, a slope of $\frac{1}{4}$ in. to the foot is common. For split or rather uneven stone surfaces used in slabs or "flag-stones," $\frac{1}{4}$ to $\frac{1}{3}$ in. to the foot is desirable.

For brick sidewalks $\frac{1}{2}$ in. or more may be necessary to prevent small puddles forming; this depending upon the kind of foundation and character of construction required by the city. Some engineers would make the cross-slope of any sidewalk at least as great as the longitudinal slope, so that water will not tend to follow the sidewalk down hill for a distance greater than its width. Probably $\frac{1}{5}$ in. to the foot (New York City's standard) is the flattest and $\frac{2}{3}$ in. the steepest cross-slopes which will prove satisfactory for sidewalks. Gravel walks and the like are generally crowned in the middle, the surface water soaking through them and the bordering planting strips. Sod between sidewalk pavement and gutter should slope at least $\frac{1}{2}$ in. or 1 in. to the foot, and adjacent to the walk should be 1 in. below the surface of same. On either sidewalk or roadway, transverse grade is undesirable except for the necessary draining off of rain water.

Ancient streets (which had no separate sidewalks) sloped to a central gutter. A few modern streets do so, such as those in the irrigated districts which have drainage ditches down their centers; and in most alleys, because they have no sidewalks to separate side gutter from building line and are too narrow to require two gutters, this construction is best and cheapest. Some still advocate central gutters for all streets. Objections to this are that standing teams should be nearest the houses, which requires moving traffic to be in the center of the street; therefore center of street should be the flattest part and otherwise most favorable to traffic. With a flat dished cross-section, the water would occupy several feet (10 to 20) in the center of the street. (If, however, there is in the street center a parkway, railway strip or other continuous strip, the roadway may slope from sidewalk continuously toward this.) It is possible that a central channel with a grating or other form of cover to admit surface water might be designed, which would be flush with the pavement and carry traffic; but no satisfactory one has yet been produced. It also generally requires more excavation and consequently more expense to dish the roadway than to crown it.

In the case of one-sided streets, roadways divided by walls longitudinally (described later), and some other constructions, the slope may be away from the sidewalk. The idea should be to throw the pavement drainage to those points where it can be most conveniently removed and at the same time cause the least inconvenience to traffic.

When next to the sidewalk, the gutter should be several inches below it so that the water flowing in it may not reach the walk and certainly not reach the buildings. It would be dangerous and objectionable to vehicles if in the form of a channel out of which a wheel could not readily rise, although in some cities a depression of $\frac{1}{2}$ in. to 1 in. below the roadway is made in residence districts, generally by setting brick on edge between gutter and roadway pavement where each of them are of brick likewise. But usually the gutter is formed by somewhat increasing the roadway slope as it approaches the curb line, or in some cases by running a continuous slope from street center to curb. The sidewalk, if paved to the gutter line, has a curb between it and the gutter. If there is a planting strip next to the gutter, there may be a curb of some kind, or the grassed land may take a rapid slope to the gutter.

In case the lot level is considerably above that adopted for the street, there may be several solutions of the sidewalk location, as indicated by the sketches. The lot may terrace to a sidewalk which is at the roadway level; or to a sidewalk from 2 ft. to any height above roadway level, a terrace* connecting sidewalk and roadway (in which case the planting strip should be as wide as possible); or, if the sidewalk is 3 ft. or more above the roadway, a retaining wall may occupy the curb line, and the sidewalk may either be placed adjacent to this (which is dangerous unless a fence be provided on top of the wall), or a planting strip be interposed to largely obviate this danger. The last plan is especially applicable in many cases where it is desired to

* A terrace should not be steeper than 2 to 1, and 3 or 4 to 1 can be maintained more satisfactorily. If this slope cannot be obtained, a combination of terrace and retaining wall may be desirable.

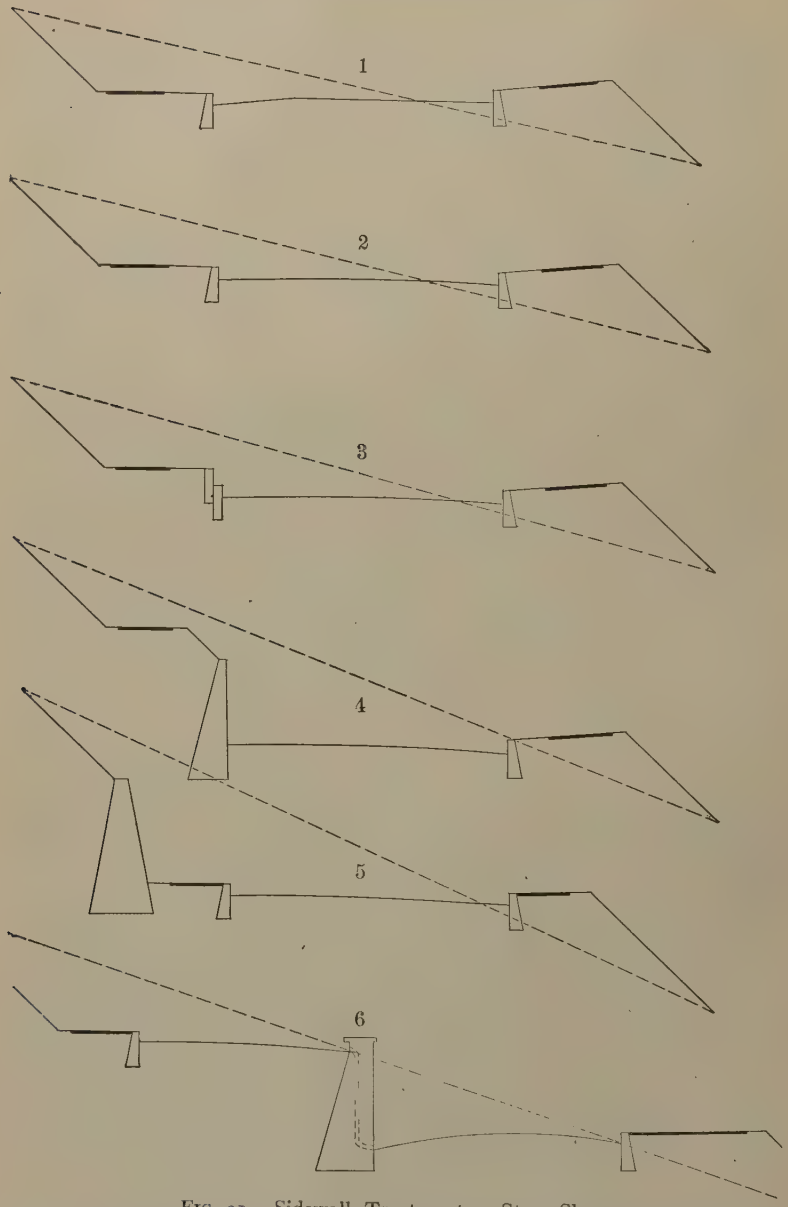


FIG. 31.—Sidewalk Treatment on Steep Slopes.

In 1, roadway has "lop-sided crown," in the others the gutters are at the same level and the crown symmetrical. In 5 the roadway is nearer the lower street line. In 6 is shown a two-level street, the upper roadway draining to the lower through pipes built into the retaining wall.

save shade trees in lowering a street grade, the sidewalk grade being left at that of the ground around the trees.

FIG. 32.—Elevated Sidewalk with Retaining Wall.

FIG. 33.—Sidewalk Steps in Syracuse, N. Y.

The plan of leaving a high sidewalk decreases excavation cost, and is often much more desirable from the viewpoint of the

abutting residents. Its chief disadvantage is the difficulty of treatment at intersecting streets. Steps down to the roadway level may be introduced here, or a slope back on a 5 per cent to 10 per cent grade where practicable. Steps are frequently introduced opposite residences, where the wall is more than 2 ft. high, to permit persons to enter and leave carriages, delivery wagons, etc. Steps are also used where terraces are introduced between sidewalk and roadway. Such high sidewalks in a resi-

FIG. 34.—Sidewalk Steps in Syracuse, N. Y. An upper and lower sidewalk level are connected by steps, as well as the latter and the roadway.

dence street are not objectionable, and keeping them at the original ground surface (while the roadway is graded to a uniform slope) reduces cost of grading and height of steps to residences and permits saving trees in many cases.

But high sidewalks are objectionable in a business street, where carriages must draw up at all points and pedestrians cross, and sidewalk pavement continues to the curb line. In such streets the curb should not exceed 4 to 6 or 8 in. in height. If regrading a street would bring the sidewalk 10 to 24 in. above the roadway and lowering it would be very expensive or detri-

mental to merchants, double or triple curbs may be built, in the form of steps, each with 5 in. to 8 in. rise. If the sidewalk is left lower than the roadway in regrading, a temporary treatment (until adjacent buildings are rebuilt) is to place a retaining wall between roadway and sidewalk, carrying it say a foot above the roadway to prevent the surface water therefrom reaching the sidewalk, also constructing a deep gutter at the foot of the wall to carry off the sidewalk drainage.

The sidewalks in many cities in hot countries and in some

FIG. 36.—Double Curb, Columbia, S. C.

ancient cities in others (as Chester, England) have their sidewalks entirely within the building lines of the street, occupying what is practically a part of the ground floors of the buildings and overhung by the upper floors. This economizes space and affords shelter from sun and rain, and for the latter reason is desirable in tropical cities. But the exclusion of sun and rain (which latter washes the sidewalks) is objectionable for sanitary reasons; the lighting of the ground floors of the buildings is poor; and for furnishing abundant light and air it is the distance between the upper parts of the houses which counts and not that

between the lower parts. But this plan offers a solution where the roadway needs widening for traffic purposes, while the houses are low and sufficiently far apart to insure abundant light and air.

Where the street adjoins a freight yard or other area to which there is no access for pedestrians, a sidewalk on that side may be unnecessary. Where there are few pedestrians and the vehicles must be given access to most of the buildings, as in a warehouse street, the foot walk may well be located in the middle of the

FIG. 36.—Sidewalk Next to Gutter.

street, and the roadway on each side rise with a continuous slope to the buildings. Other special cases may be treated to advantage by special arrangements of ways for foot and wheel traffic, and watch should be kept for opportunities for advantageous variations from the standard arrangement.

While the common practice is to place a planting strip between the curb and sidewalk pavement, several cities have tried placing the latter in contact with the curb. Memphis, Tenn., and Toronto, Ont., with a number of cities between, have laid out streets in this way. Where the terrace is high, this

gives more room for it between sidewalk and private property if it is allowed to extend beyond the street line. It also appears to give the abutting owner more land, since the paved sidewalk is further from his house. The trees, being further back from the curb, do not shade the street so much and the roadway dries out more quickly. (Sometimes this is an advantage, sometimes not.) This location of trees also makes the street appear to be wider. In general this construction seems to be preferred for narrow streets, when at all. Objections to this location are that the pedestrian is more likely to receive dust and mud from

FIG. 37.—Saving Trees by Diverting Sidewalk and Roadway.

the street; it brings him too near the storm water inlet (when this is at the curb corner) in stepping to or from the roadway; he does not have so good an opportunity to avoid vehicles which may be turning the corner as he starts to cross the street; and if the curb line is rounded at the corner, he finds it more awkward to step onto or from this than where the curb is straight and normal to his line of motion. If a carriageway crosses the sidewalk, the entire slope up from the gutter must come in the paved portion; whereas if there were a planting strip next to the curb, the slope could all occur in this space, and the sidewalk pavement be unbroken in surface. The majority of people also seem to

consider that the planting strip next to the curb adds greatly to the appearance of the street.

Where a tree interferes with the location of sidewalk pavement chosen for the street in question, it is better to carry the pavement around the tree than to remove the tree. Where there is a planting strip on each side of the sidewalk, the pavement can wind about to pass such trees without difficulty. Where a tree stands partly outside the curb line, the gutter can be bowed out to pass around it, the whole roadway being swung out of line if necessary.

A curb is necessary where the sidewalk pavement continues out to the gutter, to protect the edge of the pavement and prevent wagons from trespassing on it. It serves as a finish to the sidewalk pavement and in fact may be only the edge of this faced up. It should seldom if ever be less than 4 in. high, as less will not afford protection from vehicles. It is perhaps most frequently 6 in. high (above the gutter), and should never be more than 9 or 10 in. in a business district, unless a double curb be used, as it makes too high a step in crossing the street. A 4-in. or 5-in. curb is cheaper and stronger than a higher one and the author considers it preferable unless so deep a flow of surface water is anticipated as to overtop this and flood the sidewalk.

Where there is a planting strip next to the gutter a curb may be used, in which case 4 in. is ample for any condition not demanding a retaining wall. In many residence sections the curb is omitted and the sod continues directly to the gutter, which then is generally of cobble; or the sod may continue across the gutter, the latter being merely a swale. The objection to the latter is the danger that the grass will not be kept trimmed, that wagons will drive over and damage it, and that the grass will spread into the roadway, giving an unsightly ragged edge to the sodded strip. A curb protects the grass from teams and muddy water, prevents its spreading into gutter or roadway and gives a finished appearance to both sidewalk and roadway. But it detracts from the semi-rural appearance desired by many for a residence street, and adds to the cost.

Street Crowns. The roadway should be perfectly level transversely to be most favorable to traffic, but must have some transverse slope at every part to cause surface water to flow to the gutter. It is most satisfactory to make the opposite curbs at the same grade, and crown the roadway in the middle with equal cross slopes each way to the curbs. The crown desirable will vary with different kinds of pavement; the smoother and more durable the pavement the flatter it may be. There should be such slope that every depression (not sufficient to need repair) will drain to the gutter; and it must be remembered that the center of the roadway, which carrries the most traffic, will wear down faster than the sides, but must drain to the gutters throughout its useful life. The following crowns represent ordinary practice

Kind of Surface.	Crown (Ratio of rise to width from curb to highest point).
Earth	1 : 20
Gravel	1 : 25
Macadam	1 : 30
Bituminous macadam	1 : 35
Stone block (rough)	1 : 35
Stone block (smooth)	1 : 40
Brick	1 : 45 to 1 : 50
Asphalt	1 : 45 to 1 : 60
Wood block	1 : 50 to 1 : 60

Andrew Rosewater recommended the following rule for varying crown with grade of street:

$$\text{For smooth, hard pavement, crown} = \frac{w\,(100-4f)}{3{,}500}.$$

$$\text{For stone block and macadam, crown} = \frac{w\,(100-4f)}{3{,}000},$$

in which w = distance from curb to apex, in feet, and f = feet fall per 100 lineal feet of street; but this seems to give too much crown for smooth pavements and too little for macadam. Other

engineers would *increase* the crown as the grade increases to prevent the water from following slight ruts or depressions. The author prefers no change because of grade.

The form of cross-section of roadway may be an arc of a circle, ellipse or parabola, or two straight lines joined by a circular arc. The chief objection to the last is that when traffic slightly wears the surface it will become dished at the quarter points (midway between crown and gutter) and fail to drain to the gutter. Of the three curves it makes little difference which is used, since with a crown of only 1 in 40 or 50 it would be difficult in practice to make the variation between the theoretical and actual less than the slight differences of these three among themselves. The parabolic is easiest to stake out, by the rule that the distance below a horizontal tangent to the crown varies as the square of the distance the point is from the crown. To illustrate: Assume crown is one (foot or other unit) above the gutter; then the distance each point is below the crown level is:

Distance from curb	0	$.2d$	$.4d$	$.6d$	$.8d$	d
Distance below tangent	1.0	.64	.36	.16	.04	0.0

in which d is distance from curb to crown.

The slope or curve is generally continued without break to the curb, where there is one; although in some cases the gutter is made horizontal for a width of 12 inches or so.

On side hills it is sometimes necesssary that one sidewalk be considerably lower than the other, and this generally requires that one gutter also be lower than the other. The crown may then be retained at the center of the roadway, and the slope to the lower gutter be made as steep as is necessary to provide the minimum slope to the other gutter. Or the standard slope may be run from each gutter, letting the crown come where it may. The latter may give a continuous slope from one gutter to the other. There is a limit to the transverse slope which can be used comfortably by teams, which is probably about 1 in 30 for smooth pavements and 1 in 20 for macadam. Consequently

FIG. 38.—Two-Level Street at Chattanooga. Side street connects with upper level at its highest point.

the permissible difference in gutter elevations is limited by this. For thoroughfares a one-slope roadway is highly objectionable, and for any street the comparatively level strip furnished by a crown is highly desirable. It is advisable whenever possible to avoid "lopsided" streets and place the crown in the center, using stepped curbs or terraces at the upper sidewalk, if necessary. The cost of grading and slope of terrace on such a side-hill street may be reduced by making the sidewalk space narrower on the lower than on the upper side of the street.

Where the difference in level of sidewalks is considerable, a two-level street has sometimes been constructed; the roadway being divided longitudinally by a retaining wall. In some cases the upper roadway has been made 10 or 15 or even more feet above the lower. If this separation of levels continues for more than one block, the cross streets may break level at the wall, the section above being in grade with the upper level, and that below with the lower level of the two-level street. Or the upper level may be broken and come to two dead-ends at the cross street. In extreme cases the upper level may cross the lower cross street by means of a bridge. Each level of roadway should be at least 18 ft. wide, with one sidewalk 6 or more feet wide; but the lower roadway and sidewalk should be wider if posssible, because of the obstruction to light and air furnished by the wall and buildings opposite.

A two-level street is frequently of great advantage along a water front, the lower level being used for access to water craft, handling freight, etc., and the upper level as the thoroughfare, the two being connected by frequent ramps and steps. In many cases the upper level simplifies the matter of approaches to bridges across the river.

Where there is a street railway, the surface water cannot cross the rails until it attains some depth, but must generally follow the track and be removed through an inlet between the rails at the low points, and also at intermediate points if the grades are long. The surface between rails is generally made level; but there is the argument in favor of dishing the pavement

between rails that it tends to prevent water entering between rail and pavement, where it frequently works injury to both. In a few cities, on other than business streets, the track or tracks are placed along the side of the road, between roadway and sidewalk. In such case the railway strip may be sodded and a sodded swale gutter be provided along each side; or a curb along each side of the strip, with a gutter outside each curb.

FIG. 39.—Double Car Tracks along Side of Roadway, Newton, Mass.

Two car tracks next to curb give four lines of traffic alternating in direction, which increases danger to pedestrians crossing the street, as proved by records of accidents in New York city.

ART. 10. STREET GRADES

A level street is most favorable to traffic; but some grade is desirable to remove the surface water. This flows off of street crown to gutter and in gutter to a sewer inlet or a water course.

The gutter is therefore where the grade is needed, and this grade should be no flatter than that necessary to remove the water at sufficient velocity to prevent flooding the sidewalk and to prevent puddles standing in minor inequalities in the gutter surface. The minimum grade established by the Corps des Ponts et Chaussées is 0.8 per cent; by the Troy improvement commission, 0.75 per cent. For asphalt streets and gutters

flatter grades are used (Seventh avenue, New York, has a grade of about 0.22 per cent for 1½ miles above Central Park), and wood block and well laid brick may have the same. The author suggests 0.25 per cent for asphalt or wood block; 0.25 to 0.50 for brick or flag; 0.75 per cent for stone block, and 1 per cent for cobble gutters, as minimum permissible grades.

The gutter grade may be steeper than that of the roadway center or the curb, but this is somewhat unsightly, and besides gives a high curb at the corner, where the street crossing is located, unless an inlet be placed above the crossing. Moreover, there is only a slight range of desirable crown elevation (above gutter) for a given kind of road pavement. An increase in curb height from 4 to 10 in. is probably the maximum practicable (unless a stepped curb be used), permitting a minimum grade for smooth gutter for 200 ft. each way from the middle of a block with a level curb. If curb and roadway are level, a better plan is to put sewer inlets every 200 ft. along each curb and give the gutters a fall of say 0.33 per cent to each one from points midway between them, varying the curb face from 4 in. to 8 in. It is probably preferable in most cases, however, to give both roadway and sidewalk the undulating grade of the gutter, making this 0.25 per cent, which would increase the tractive resistance inappreciably.

Traction. The most important feature of street grades is the resistance they offer to traction.

Traction is the force exerted in drawing a vehicle. Resistance to traction is composed of axle friction, rolling resistance and grade resistance.

Axle friction depends upon the nature of the bearing surfaces and is equal to the load times a coefficient which varies approximately inversely as the square root of the load. The coefficient is about .02 for light carriages; .015 for heavier carriages; .012 for loaded thimble-skein wagons; all with good lubrication. If the lubrication is poor the coefficient may be two to six times as great. Thus axle friction may be from 24 lbs. to 240 lbs. per ton hauled.

Rolling resistance is caused by the flattening of the wheel at the point of contact with the road, and the yielding of the road under the wheel, and by obstructions in the road. Force is required to produce the flattening of the wheel and to raise the wheel out of the depressions in the road surface and over stones, ruts and other obstructions.

These two resistances are assumed to be the same on all grades as on a level, although this probably is not strictly correct for the latter.

Grade resistance varies directly with the rate of grade.

Table XV

RESISTANCE DUE TO GRADE, POUNDS PER TON

Rate of grade	Level	1 : 500	1 : 100	1 : 80	1 : 60	1 : 50
Per cent grade	.....	0.2%	1%	1¼%	1⅔%	2%
Angle with level	.....	0° 6′ 53″	0° 34′ 23″	0° 42′ 58″	0° 57′ 18″	1° 08′ 16″
Tractive resistance per ton caused by grade	0.0	4.0	20	25	33⅓	40

Rate of grade	1 : 40	1 : 30	1 : 25	1 : 20	1 : 15
Per cent grade	2½%	3⅓%	4%	5%	6⅔%
Angle with level	1° 25′ 57″	1° 54′ 37′	2° 17′ 26″	2° 51′ 21″	3° 48′ 51″
Tractive resistance per ton caused by grade	50	66⅔	80	100	133⅓

Rate of grade	1 : 10	1 : 8	1 : 6	1 : 5	1 : 4
Per cent grade	10%	12½%	16⅔%	20%	25%
Angle with level	5° 42′ 58″	7° 07′ 30″	9° 27′ 43″	11° 18′ 36″	14° 02′ 10″
Tractive resistance per ton caused by grade	200	250	333	400	500

This resistance is in addition to that required on a level. Example: If it require 25 lbs. traction to pull one ton over a certain level road, it would require 50 lbs. to pull the same load up a 1¼ per cent grade with the same kind of road surface; and nine times as much up a 10 per cent grade as on a level.

The amount of traction on a level varies approximately as the load, the ratio varying less than the error involved in selecting the coefficient. This error is due to variable factors involved in the team, driver, nature of surface, width of tire and diameter of wheel, design and condition of vehicle, method of loading, curves, etc. The results of any series of experiments are there-

fore to be accepted as only approximately applicable to any other conditions. Many sets of tests have been made by use of a dynamometer, the results of several of which are given in the table.

TABLE XVI

TRACTIVE RESISTANCE (POUNDS PER TON) ON LEVEL ROADS OF VARIOUS SURFACES

Character of Road	Coefficients Determined by Several Tests						
Loose sand	320[1]	400[2]					
Ordinary cobble	250[2]	125[5]					
Ordinary dirt	200[2]						
Bad macadam	143[3]						
Good cobble	54[1]	133[2]	66[2]	62½[5]	65[13]		
Old macadam	80[2]	100[6]					
Good macadam	57[2]	66⅔[8]	36[8]	46[11]	38[11]	40[13]	
Best macadam	38[1]	40[2]	15[7]	38[7]	18[4]		
Best clay	98[1]	100[2]	66[2]	100[11]			
Hard gravel	51[1]	44[7]	66⅔[9]	66⅔[10]			
Granite blocks	42[1]	80[2]	85[7]	33[10]	29[4]	46[12]	34-40[13]
Wood block	35[7]	48[12]	36[4]	50[4]	90[4]	33[11]	
Brick	37[4]	25[4]	22[4]	24[4]	17[4]	20[13]	35[12]
Asphalt	26[1]	15[2]	24[7]	34[4]	70[4]	16[13]	67[12]
Smooth granite trams	12[2]						
Iron trams	10[2]	19[4]	40[4]				
Plank road	32[4]	40[4]					

References: [1] U. S. government tests. [2] Prof. Haupt. [3] Gordon. [4] Prof. Baker. [5] Kossack. [6] Navier. [7] London tests. [8] Morin. [9] Bevan. [10] Minard. [11] Kansas State Agricultural College. [12] Toronto tests, dry weather. [13] Tillson.

Prof. McCormick, of Kansas State Agricultural College, says that a 2800 lb. team can pull 933 lbs. on a level for a short period of time, and 28 lbs. less for each 1 per cent of grade, or 653 lbs. on a 10 per cent grade.

The city engineer's office of Toronto found the coefficients given in the table for dry weather, but for wet weather found 41 for wood block, 57 for asphalt and 74 for cedar block. They also found the effect of the slope to vary, the resistance for brick being 35.4+18.3 (per cent of slope); for granite block, 46+30.75 (per cent of slope); for asphalt 67.3+26.1 (per cent of slope). (Theoretically each should be 20 times per cent of slope.)

The importance of grade on well paved streets is evident. On a 2 per cent grade on wood block pavement, only about one-

half as heavy a load can be drawn as on the level, and on a 4 per cent grade only one-third as much. On an old macadam road, however, a 4 per cent or 5 per cent grade will reduce the load only one half. The desirability of flat grades on thoroughfares is evident.

Table XVII

EFFECT OF SIZE OF WHEELS UPON TRACTION

TIRES 6 IN. WIDE. LOAD 1¾ TONS

(From Bulletin of Missouri Agricultural Experiment Station.)

Description of Road Surface	Mean Diameter of Front and Rear Wheels—Inches		
	50	38	26
	Tractive Force Lbs. per Ton		
Macadam; slightly worn, clean, fair condition	57	61	70
Gravel road; dry, sand 1 in. deep, loose stones	84	90	110
up grade 2.2%, ½ in. wet sand, frozen below	123	132	173
Earth road, dry and hard	69	75	79
½ in. sticky mud, frozen below, rough	101	119	139
Timothy and blue grass sod; dry, grass cut	132	145	179
wet and spongy	173	203	281
Cornfield; flat culture, across rows, dry	178	201	265
Plowed ground; not harrowed, dry, cloddy	252	303	374
Average value of the tractive power	130	148	186

Morin, from experiments with 2½-in., 4½-in. and 6½-in. tires, concluded width had no effect on a solid pavement, but on a compressible surface, traction decreased as width increased. More recent experiments seem to indicate that on hard surfaces traction increases with the width of the tire, but inversely as the width on compressible surfaces.

It requires from two to six times as much tractive force to *start* a vehicle as to keep it in motion on a level at two or three miles per hour.

Traction increases as *speed* increases. Doubling the speed from a walk to a trot seems to increase the traction by about one-third on macadam; less than this on smoother pavements.

The *angle of repose* for any pavement is that grade at which a vehicle will just be at the point of starting to move from its own weight; axle friction being that of a well lubricated average axle. Angle of repose (expressed as per cent grade) $= \frac{1}{20}$ (tractive resistance in pounds per ton). On a road whose grade is the angle of repose, a horse will need to neither pull nor hold back in going down hill. If all heavy loads move in this direction, this grade is therefore the most desirable. Using Tillson's values above, this grade is, for granite, 1.7 per cent to 2 per cent; for asphalt, 0.8 per cent; for brick, 1 per cent; for Belgian block, 2 per cent; for macadam, 2 per cent; for cobble stone, $3\frac{1}{4}$ per cent.

The *power of a horse* has been given the average value of 165 lbs., or $\frac{1}{5}$ the average weight of a horse. For a stretch of 2000 to 2500 ft. he can exert double this. On a level this is his tractive power; on a grade part of it is used in raising his own weight, which part is $\frac{1}{100}$ (horse's power) $\times$ (grade resistance for 1 ton, in Table XV).

Example: What weight can a horse draw up a long 4 per cent grade on a macadam road? Weight of horse 1000 lbs. Answer: Power $= \frac{1000}{5} = 200$ lbs. Tractive power $= 200 - \frac{200 \times 80}{400} = 160$ lbs. $160 = W(80+40) \therefore W = 1\frac{1}{3}$ tons. (Includes weight of wagon.) For a short spurt he may pull double this. On an asphalt road he can pull $1\frac{2}{3}$ tons (if the foothold is equally good).

The above power ($\frac{1}{5}$ his weight) can be exerted when traveling at 175 to 200 ft. per minute ($1\frac{3}{4}$ to $2\frac{1}{4}$ miles per hour); the pull will be inversely as the speed. According to this an 800-lb. horse at 8 miles per hour can exert $\frac{2}{8}$ of $\frac{800}{5} = 40$ lbs. tractive power on a level; or 300 lbs. of carriage and 300 lbs. of men up a 2 per cent macadam road.

On a short ascent, lifting a pile-driver hammer, etc., a horse can pull 500 lbs. at 2 miles per hour. (A "horse-power" is equivalent to 188 lbs. at 2 miles per hour.)

For automobiles the tractive resistance is the same in theory, but the practical coefficients will vary with the kind, size, etc., of tire used. The tractive power is that of the engine, limited by the weight on the driving wheels, times the coefficient of friction between these and the pavement, times the cosine of the angle of the grade.

By use of the factors and theories just given, we may calculate the length of low-grade detour requiring the same amount of energy as a given length of high-grade direct ascent of a hill. Assume a 10 per cent grade, brick pavement, one mile long; then the tractive resistance is about 225 pounds per ton. If a detour on a 2 per cent grade, same pavement, is proposed, the tractive resistance on this would be 65 pounds per ton, or only about 29 per cent as great. Consequently a horse could draw (theoretically) about $3\frac{1}{2}$ times as heavy a load on the detour at a given rate; or could haul the same amount of total loads per day if the detour be $3\frac{1}{2}$ miles long. Also the speed of a carriage horse hauling a light carriage could be 2 or $2\frac{1}{2}$ times as great on the more level road.

For automobile trucks the calculation is somewhat different. Pleasure automobiles can climb 8 or 10 per cent grades at perhaps three-fourths the speed allowed on city streets, and the additional gasoline consumed will probably not exceed by more than 5 per cent to 10 per cent that used on the level; and grades are therefore serious matters for trucks only. Neglecting the gasoline consumed (the variations in amount of which are negligible relative to the uncertainties of assumption and calculation), assuming a 2-ton truck, and average speeds of $10\frac{1}{2}$ miles per hour on high gear, 6 on intermediate, and 3 on low; and pavement offering a tractive resistance on the level of 40 pounds per ton; and calculation (based on standard methods of calculating automobile power) indicates that there would be little reduction in speed or load necessary up to a 3 per cent grade; but if the grade exceeded this and was less than 8 per cent a drop to intermediate speed would be necessary and a detour $1\frac{3}{4}$ times as long, if level, could be covered in the same

time; while if the grade exceeds 8 per cent, a level route could be covered in the same time if $3\frac{1}{2}$ times as long. For a 5-ton truck of standard construction the critical grades would be $2\frac{1}{4}$ per cent and 7 per cent.

Maximum Grades. The tractive power of either horse or automobile is affected by the slipperyness of the pavement or the foothold offered. With a slippery pavement, a grade may easily be reached on which the horse can not walk even without a load. This sets a practical limit to the grades for different kinds of pavement; but this is by no means definite, and engineers have differing views on what grades should be considered maximum. S. C. Thompson, engineer of highways of Bronx borough, New York, considers 3 per cent a limit for sheet asphalt and creosoted wood block; 6 per cent for asphalt block; 4 per cent or 5 per cent for vitrified brick; for soft granite or Medina sandstone, 13 per cent or more. Asphalt has been laid on a 17 per cent grade in Pittsburgh, but this is by no means recommended. San Francisco has grades of $25\frac{1}{2}$ per cent, $21\frac{1}{2}$ per cent and 18 per cent on Sacramento street; Rochester, N. Y., 17.8 per cent on Ely street; Cincinnati, 16 per cent on Sycamore street; Baltimore and Parkersburg, W. Va. have 15 per cent grades. The city of New York some years ago adopted 18 per cent as a maximum grade for its thoroughfares. The Troy (N. Y.) Improvement Commission adopted 7 per cent as a maximum grade.

In general, streets in and near transportation centers should not have grades exceeding 2 per cent or 3 per cent, nor those in the business districts to exceed 5 per cent or 6 per cent, regardless of cost. In residence districts in a hilly country, local streets should not exceed 10 per cent to 16 per cent, and diagonals and main thoroughfares 6 per cent to 10 per cent. (In a flat country, one-half to one-third of these may be set as maximum.) To secure these grades, it may be necessary to make some deep cuts or fills, or to run diagonal streets back and forth across a hillside. (Make turns as few as possible, for these are expensive to construct, and dangerous to traffic.) As suggested before, a long diagonal of 5 per cent or 6 per cent may be provided for

heavy loads, and more direct and steeper streets for light loads; while for foot traffic, lanes with 10 per cent to 20 per cent grades, or flights of steps, may be provided leading straight up the hill, or diagonally up the face of a cliff.

For local streets, one-sided streets may be used, or two-level streets. Or, if a grade less than 12 per cent or 15 per cent is impossible, a local street may be made "no thoroughfare" for vehicles, a practicable grade run each way from the two ends of a block toward the center, where the two would then be at considerably different elevations; and a retaining wall built across the street at this point, being carried about 3 ft. above the level of the upper street to prevent accidents. Steps may connect

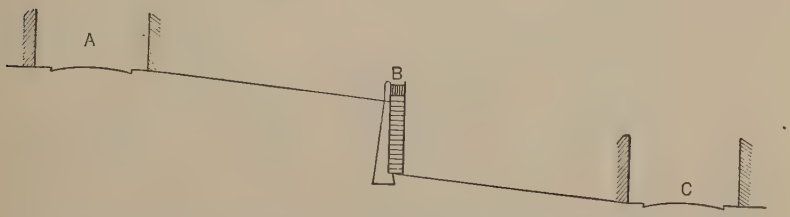


FIG. 40.—Broken-grade Street. Connects streets *A* and *C*, with break in grade and retaining wall at *B*, where steps connect the two levels.

the upper and lower sidewalks, built either parallel with the street line or carried down the face of the wall, as in Fig. 40.

Another plan is to zig-zag a roadway with short loops. Sixth street, Burlington, Ia., 80 ft. wide, has an 18-ft. roadway which zig-zags with turns having a radius of 12 ft. on the inner edge, and thus reduces a 24 per cent slope to $14\frac{1}{2}$ per cent roadway grade. The surface is terraced and sodded between loops of the roadway. For mounting very steep slopes, inclined elevators or "inclines" are sometimes used, operated by cable. But these are subject to accidents. Pittsburgh, Pa., at one time had 11 of these, double track, from 300 to 2000 ft. long, for both teams and passengers, but is substituting diagonal streets, tunnels, and long, elevated approaches for most of them.

For thoroughfares across valleys, grades are largely eliminated

by carrying a viaduct from one side to the other, generally approximately level—Hawk street, Albany; 155th street, New York; 16th street, Denver. In some cases the viaduct carries two or more floors at different levels to connect a similar number of thoroughfares on the two hillsides; or two floors, one rising and the other falling, may connect one level on one hill with two levels on the other.

Planning Grades. In every vertical location of a street, economy of construction of street and relative elevations of abutting property should be considered. In general, a street should never, if it can be avoided, be higher than the front of abutting land (except in business districts where buildings are placed at the street line and none of the natural surface remains). This avoids placing pavements on a fill, which is objectionable; makes it possible to place the sewer low enough to drain the down-hill houses without excessively deep trenching, and provides surplus earth for grading up the lots on the lower side. As a limit, the cut for the upper sidewalk should be at least three times as great as the fill for the lower; in which case the roadway pavement will all be on natural soil foundation and only the sidewalk in fill, and the surplus earth will suffice to grade the lower lot back to the house front. The author suggests $f=\frac{1}{3}(c-5)$, in which f is the depth of fill at the street line and c the depth of cut at street line. If d equals difference in elevation of surface at street lines, $c=\frac{3d+5}{4}$.

When a house is within 10 ft. of a street line, its first floor should generally be at least 2 or 3 ft. above the sidewalk level. Up to 8 or 10 ft. is not objectionable if the house can set back say three times that distance from the street line. (A terrace steeper than $2\frac{1}{2}$ to 1 is bad practice—difficult to cut the grass on and prevent heavy rains from washing; 4 to 1 to 6 to 1 is much more satisfactory.) If the upper lots would be more than 10 or 15 ft. above the roadway, retaining walls, elevated sidewalks, two-level streets, etc., may be employed. The roadway may be placed nearer the lower than the upper street line to provide for

a terrace from an elevated sidewalk. Local streets may advantageously follow a uniform grade with a fairly constant cut, with such curves as the topography necessitates. Thoroughfares, however, should be straight, or with as few bends as possible, even though considerable grading be necessary.

A grade should be continuous or change gradually with vertical curves, so far as possible. A grade on a thoroughfare should be continuous at almost any expense of grading or modification of intersecting streets. Every flattening out of a grade at one point must necessarily be compensated by a steepening at other points, which is to be avoided where heavy traffic uses the road. Where any steep grade crosses another of greater traffic importance, however, the former must be flattened more or less in crossing the roadway. A common rule is to carry the steeper grade up to join the down-hill gutter of the thoroughfare, follow the regular cross-section of the roadway up to the crown, carry it level from crown to up-hill gutter, and then resume the steep slope; but it gives a better appearance to carry a 3 per cent slope (unless that of the cross street is less) from crown to upper curb line. Where two streets of considerable grade and equal traffic importance cross, each may be modified as suggested above.

If the grade of a thoroughfare is not uniform throughout, the steepest part should not have more than double the average grade of the street, nor should any such steep stretch exceed 1000 to 1500 ft. in length. If this can be done, the steep stretch will not seriously affect the weight of load which can be drawn up the grade.

A break in grade should never be made as an angle, but a vertical curve should connect dissimilar grades. The longer the curve the better the appearance and the easier the riding. The author suggests for the minimum length: twenty times the difference between the two grades, both grades being expressed in per cent and one being minus if they slope in opposite directions. Example: To connect a 6 per cent down with a 2 per cent down, the length $= 20\ (6 - 2) = 80$ ft. To connect a 6 per cent down with a 4 per cent up, the length $= 20\ (6+4) = 200$ ft.

Vertical curves must sometimes be shorter where the grade is flattened at street intersections—only 20 or 30 ft. frequently; but 200 to 300 ft. gives a much more pleasing appearance. In crossing main thoroughfares the angle between the main and crossing grades of the minor street may come at the property line and the curve have a length twice the width of the sidewalk. Where neither street is a main thoroughfare or for a main thoroughfare crossing a minor street, the grade angle may come at the curb line and the length of the curve be the width of the roadway. Curves

FIG. 41.—Good Appearance of Vertical Curve.

should extend the same distance each way from the grade angle. To determine the ordinates at the various points of the curve: Add the elevations at the extremities of the curve, divide by 2; subtract from the quotient the elevation of the gradients at their intersection; divide the difference by 2 and call this quotient M; call L the length of the curve in feet, and c the correction at any point d ft. from the nearer end of the curve. Then $c = \frac{4d^2}{L^2}M$. c is to be added to the straight gradient when the curve is concave upward and subtracted when concave downward.

Example: In Fig. 42 let a 3 per cent and a 7 per cent grade meet at d, with an elevation at their intersection of 90.00; to connect them with a vertical curve [20 $(7-3)$ =] 80 ft. long between the points a and b. Grade at $a = 90.00 - (40 \times .03) = 88.80$.

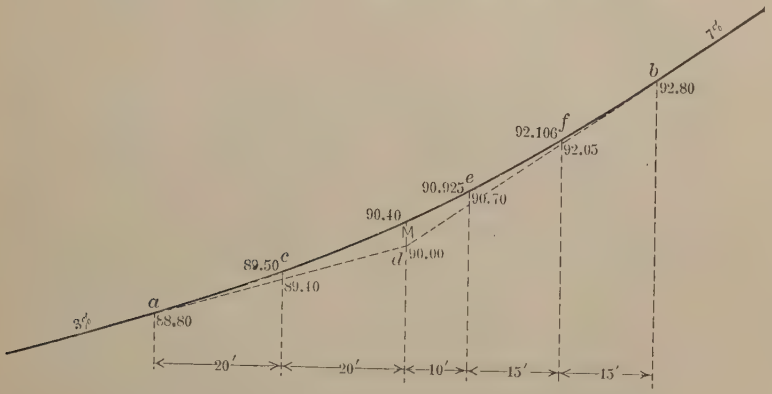


FIG. 42.—Calculation of Vertical Curve Connecting Grades.

Grade at $b = 90.00 + (40 \times .07) = 92.80$.

$$M = \tfrac{1}{2}\left(\frac{88.80 + 92.80}{2} - 90.00\right) = 0.40.$$

The ordinate from tangent to curve at c, 20 ft. from a, $= \frac{4 \times \overline{20}^2}{\overline{80}^2} \times 0.40 = 0.10$; that at c, 30 ft. from b, is $\frac{4 \times \overline{30}^2}{\overline{80}^2} \times 0.40 = .225$; that at f, 15 ft. from b, is $\frac{4 \times \overline{15}^2}{\overline{80}^2} \times 0.40 = .056$. The curve elevations are therefore as shown in the drawing.

Drainage should be kept in mind in fixing street grades. There should be no "pockets" or low points in either gutter, not even of an inch or two, which have no outlet to a natural stream or other body of water or to a sewer already in existence or built before the street is completed.

It is generally desirable to run a street longitudinally through the bottom of a swale or gulley, or else to grade up land abutting on the street, so that all surface water will drain to the street.

In Wichita and in Dodge City, Kan., streets have been made in the form of a shallow channel, low in the center and with side walls 10 in. or so high, which carries from 10 to 36 in. depth of water over its entire width after heavy rains, discharging it into a stream at the mouth of the gulley in whose bottom the street is constructed.

Effort should be made to avoid grade crossings of steam railroads, where they exist or their future location is known. If at all possible, the streets should be carried over the tracks rather than under them; a railroad fill through a town is a calamity. If the street passes over the railroad, a clearance of 18 to 20 ft. is generally required, with 18 in. to 3 ft. additional for depth of floor and girders. If the railroad is overhead, the clearance may be only 15 to 18 ft. Either plan is in most cases carried out by both lowering one and raising the other; although in high land or irregular topography the result may be secured by changing one only. The maximum limits of grades previously suggested apply to the approaches to such crossings. Provision must be made for draining the low point in the street to a sewer or some other outlet. In some cases when the street passes under the tracks, the sidewalks are not lowered so much as the roadway, but are given only 8 or 10 ft. clearance, thus being 7 or 8 ft. above the roadway at the lowest point. This gives less grade to the sidewalk and leaves it more nearly on a level with the abutting property.

Where a steam railroad or intense traffic makes crossing the same on foot dangerous or difficult, some cities have erected a bridge with a stairway at either end to the sidewalk (as in Fig. 17), or driven a tunnel underneath; but these are seldom used by pedestrians unless surface crossing is prevented by a fence, the majority of people preferring the risk of the surface to the climb to the bridge or descent to the tunnel. A few cities have carried one roadway under another by a subway where two heavy-traffic streets cross.

The grade of a street is defined by the statutes of several states as the top of the pavement at the center of the street or

center of roadway. Curb grades are really more important, however, and more likely to be permanent, and these should always be given, whether or not a roadway grade is given. If grades of both center of road and curb are given as calculated for a macadam street, it will be impossible to change the pavement later to asphalt or other smooth, hard surface and give a suitable crown and still retain gutters of sufficient depth, without changing the relative elevations of curb and road center; and such relative change can be made in the *road* when it is repaved with much less damage and expense than in the *sidewalk*. In some cities it is the regulation that the center of the roadway at each point shall lie in a straight line connecting the curbs opposite said point; but it is evident that if this rule would serve for a macadam road it would not for a smooth surface road unless the height of curb be varied correspondingly. The most logical and satisfactory plan would be to fix the elevation of each curb as established grades for that street; then arrange the depth of curb and amount of crowning suitable for each class and width of pavement.

Grades at Street Corners. Given the curb elevation, that at the property line is found by applying the transverse sidewalk grade. This leads to complications at a street corner where the elevations of the two curbs at the points opposite the point of intersection of the street lines are different; for if the same sidewalk slope (with both sidewalks the same width) be added to each elevation, we have two elevations for the same point of intersection of street lines. No really satisfactory solution of this difficulty has ever been found. Hering and Rosewater, in a report to Duluth, recommended making the elevation of the street line intersection equal the average of the two elevations so obtained, and warping the sidewalk surface for from 5 to 20 ft. back from the corner. This may give a too steep crossing slope on one sidewalk and a too flat one on the other, or even in many cases a slope toward the building line. Some would make all curbs level from a point opposite the street line intersection to the curb intersection; which solves this difficulty but requires

that the roadway grade also be level or nearly so across the intersection, which may be seriously objectionable. In some cases the warping of the sidewalk is extended 4 or 5 ft. back from the street line corner on each street, in which length the street line may take a slope of even 30° to 45°; or two or three steps may be inserted at the building line, tapering to a point near the middle of the sidewalk or between this and the curb.

After studying many rules and methods, we believe that none can be found adapted to all cases; but that in spite of this, each design should be kept as near as possible to a standard, varia-

FIG. 43.—Difficult Corner Inadequately Treated.

tions from which are confined within fixed limits. We suggest the following, based upon ideas and suggestions of a number of experienced engineers:

Center Lines. The grade of a thoroughfare should always be given preference over that of a minor street, and be continued unbroken (at least so far as the street center is concerned) across an intersection (except as topography may prevent, as hereafter described). If two thoroughfares intersect, this may apply to both, unless the grade of either exceeds 3 per cent, when it must be reduced to 3 per cent between the curb lines of the intersecting street. (In all of this discussion the grades and lines of street centers and curbs are assumed to continue

straight to the intersections. In practice, vertical curves would be used at all such intersections and horizontal curves for the curbs.)

If a secondary or local street cross a thoroughfare, it should be level from center line intersection to curb line where the grade is ascending; and on a descending side, the natural crown of the thoroughfare should be used; the grade of the cross street beginning at each curb line (unless flattened to the building line as described later).

The curb line grade is parallel to that of the center line of the street, except at the intersections; so the above may be used in determining the elevations and grades of the curb lines also throughout the length of the street; to be modified later for those sections of curb between the street lines at intersections.

Curb and Street Lines. For convenience in the description, the intersection of the street lines will be called S; the points on the curbs opposite S will be called s on one street and s' on the other; the intersection of the curbs (or where they would meet if no curve or "radius" corner were used), c; and the intersection of the center lines, I. The standard cross slope of the sidewalk will be assumed as 2 per cent (practically $\frac{1}{4}$ in. to the foot). It may be more than this, depending upon the material used. The maximum cross slope is 6 per cent; but under extreme conditions this may be increased to 8 per cent or even 10 per cent. Also under extreme conditions it may be flattened to a level cross slope but must never slope toward the street line.

The elevation of S at each of the four corners is obtained by adding to the higher s the slope of the sidewalk at 2 per cent; the slope s' S coming as it may. But if s' S then exceeds 6 per cent, s S is flattened sufficiently to reduce it to 6 per cent, if to do so does not require it to be sloped toward the building line; if it should so require, s S is made level and s' S comes as it may. But if s' S would still exceed 8 per cent or 10 per cent, the street line grade must be changed, or the curb grade of one street lowered or that of the other street raised, or both.

If either $s\ S$ or $s'\ S$ as finally adopted is not the standard cross slope, the sidewalk is warped to the standard slope at a point 25 ft. back from S.

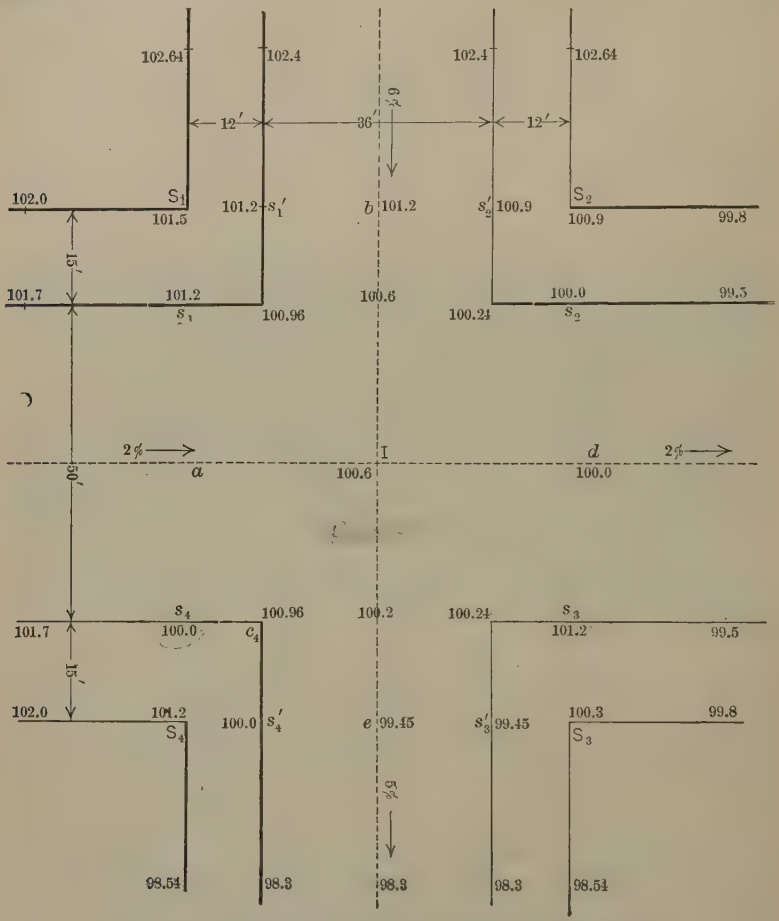


FIG. 44.—Calculation of Elevations at Street Intersection.

If starting the regular grade of an intersecting street at the curb line would make it impossible to keep the sidewalk slopes within the limits given (0 per cent and 8 per cent or 10 per cent), then the grade of said street must be flattened from curb line to property line sufficiently to permit this.

It may be necessary or advisable to make one or both streets "lop-sided" (that is, with one curb lower than the other) in order to adapt them to the slope of the crossing street; as when the grade of a thoroughfare is continued unbroken across an intersection. In such case, find the grade of each s at the thoroughfare curb from the center grade of the thoroughfare, cross slope of road-way and curb height. Use limiting sidewalk slopes to determine elevations of S and s' for each corner, in such a way as to give maximum possible elevation to the lower s' and minimum possible elevation to the upper s; the sidewalk slopes being reduced to more nearly the standard if such extreme departure therefrom is found unnecessary.

The maximum difference permissible between opposite gutters will be that which gives a cross slope of roadway of 3 per cent or perhaps 4 per cent—more than 5 per cent is seriously objectionable. If the calculation just described, using the same curb height on both sides of the street, gives a steeper cross slope of roadway than 3 per cent or 4 per cent, it may be advisable to vary the curb height, even using a double or stepped curb on the upper side.

Two illustrations of such calculations will perhaps make the idea clearer. In Fig. 44 a thoroughfare at a 2 per cent grade is crossed by a secondary street with a 6 per cent approaching and 5 per cent departing grade. The center line grade of the thoroughfare is carried uniform, that of the cross street is reduced to a level from the upper curb line to I, and dropped by the amount of crowning (0.4 foot) at the lower curb line. The curbs on the thoroughfare are both given the same elevation as the center line throughout.

The difficult corners at any intersection are those whose including lines slope, one up from the corner, the other down. (Also, in oblique intersections, the acute angles. When these two coincide, as in the next illustration, we have the maximum difficulty.) Considering S_2, we give this elevation 100.00 plus (6 per cent of 15) = 100.90. b would be 100.6 plus (6 per cent of 15) = 101.5; but s'_2 cannot be as high as this, since S_2 is

only 100.90. We accordingly make $s'_2 = 100.9$. s'_1 may be made the same as s_1 (101.2), as is always desirable when possible; and b may be 101.2, or (averaging s'_1 and s'_2) 101.05 instead of 101.50.

Considering S_4, this we will make 101.2 (the lowest possible), since the curb falls rapidly from c_4 down the cross street. The lowest s'_4 should be made is 101.2 − (10 per cent of 12) = 100.08. e would be 100.2 minus (5 per cent of 15) = 99.45. Allowing a 0.4-foot curb at s'_4, this makes e 0.15 lower than the gutter at s'_4. s'_4 cannot be lowered (without changing the thoroughfare grades); consequently either the curb at s'_4 must be made deeper, giving a lower gutter, or e must be raised or the crown of the cross street thrown to the left of the center. Assuming e not raised, the gutter at s'_3 may be made 99.05, and the curb here be made 99.45. Calculating from the thoroughfare curb, S_3 should be 100.30; and as this gives a fall from S_3 to s'_3 of 7 per cent, this elevation for S_3 may be used.

In the second case (Fig. 45), we have two streets intersecting at 45°, one with a continuous 4 per cent grade and the other with an approaching 6 per cent and departing 10 per cent. We recognize an extreme case and use limiting concessions at all points; 4 being the most difficult corner.

Each street center line is reduced to 3 per cent grade between intersecting curb lines. Each roadway is given a continuous cross slope of 4 per cent from upper to lower curb. This gives $s_4 = 103.69$ and S_4 is made the same. $e = 100.68 - (10$ per cent of $47) = 95.98$; the gutter at s'_4 becomes 96.70; curb 97.10, and 10 per cent sidewalk slope gives $S_4 = 98\ 30$, or 5.39 ft. lower than its elevation as calculated from s_4. Apparently some radical solution is necessary. We may introduce steps in the sidewalk between S_4 and s'_4, giving s'_4 elevation 103.3 at the top of the steps (as in the illustration). Or the curb at s'_4 may be made 103.3 as before, with a face 6.6 ft. high above the gutter—a retaining wall—and a sloping sidewalk substituted for the steps, laid at a grade of say 15 per cent. Or the street $b\ e$ may be carried level from I to e, making $e = 101.44$; making

the curb 10 in. high, making $s'_4 = 102.99$; and giving the sidewalk $S\ s'_4$ a 6 per cent slope. The same kind of difficulty, but

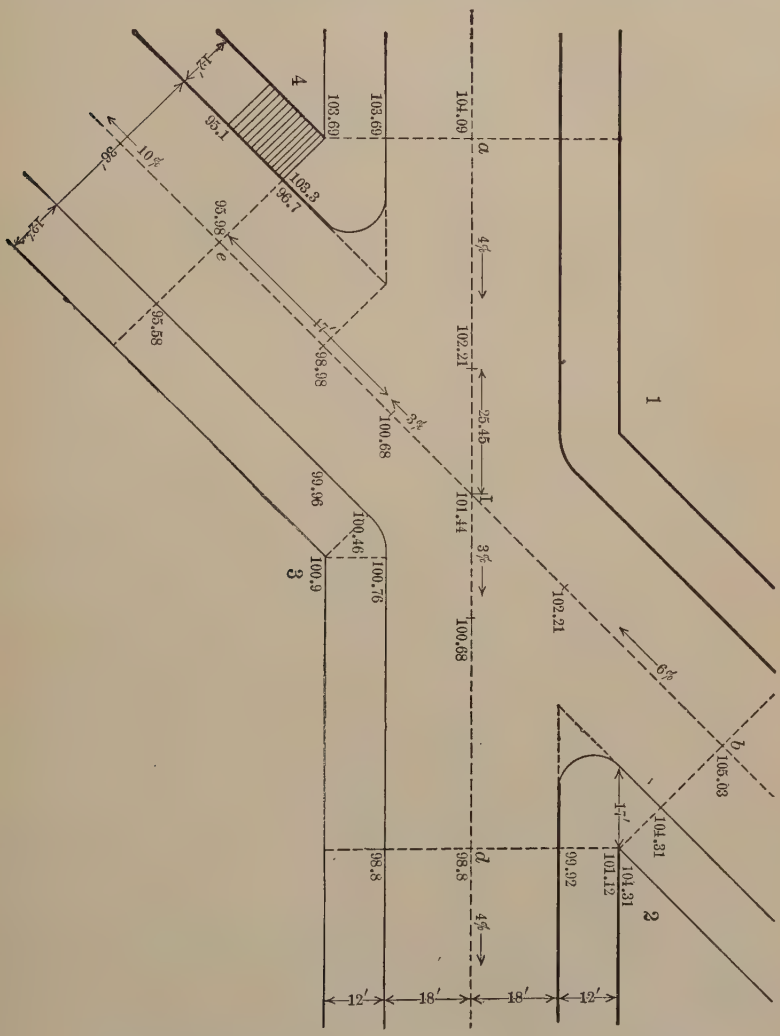


FIG. 45.—Calculation of Intersection Elevations—Extreme Conditions.

less in amount, will be found at corner No. 2. Corners No. 1 and No. 3 will give much less trouble.

For an extreme condition like the above, none of the solutions suggested is more than a make-shift. If the grades are being adjusted throughout or can be changed without too great expense, a more satisfactory solution is to reduce the center line grades between a and d, and between b and e to 2 per cent. Then $e = 99.99$ and $a = 102.89$; $s_4 = 102.49$ and $S_4 = 102.49$.

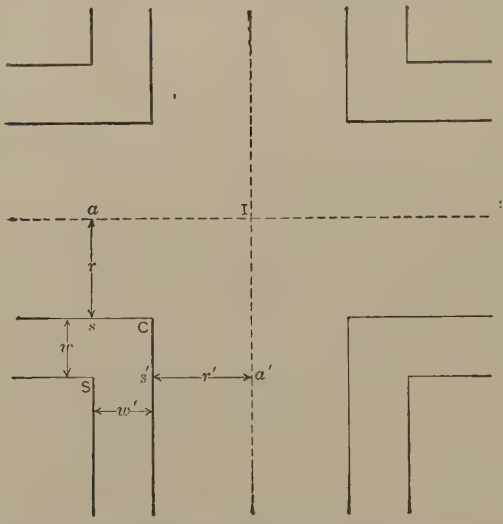


FIG. 46.—Calculation of Maximum Difference of Elevations of s and s'.

From e, $s'_4 = 101.11$ and $S = 102.32$. The difference in these values of S (0.17) can easily be adjusted by making the curb at s'_4 0.57 ft. high instead of 0.4 high. Had the crossing been a right angle one, a 3 per cent grade for the building line platform would have served.

To find the maximum difference in elevations which can be assigned to points s and s', and to the center lines opposite these points (see Fig. 46):

Let x = the maximum allowable slope of roadway (given above as 4 per cent).

y = the maximum allowable slope of sidewalk (given above as 10 per cent).

c = the minimum height of curb (say 4 in.).
c' = the maximum height of curb (say 10 in.).
r and r' = one-half the width of roadways.
w and w' = width of sidewalks.
a and a' = points in center lines opposite s and s'.
I = intersection of center lines.
g = grade of center line from a to I.

Maximum difference between s and $s' = w'y$.
Maximum difference between a and $a' = r'x + c' + w'y - c + rx$.
Inserting values given for x, y, c and c', we have

$$a - a' = .04(r + r') + \frac{6}{12} + .10w'.$$

Example:

Street $a\ I$ is 80 ft. wide, 16-foot sidewalks, 48-foot roadway.

Street $a'\ I$ is 60 ft. wide, 12-foot sidewalks and 36-foot roadway.

The former is a thoroughfare with a grade of 3 per cent, which is not changed at the crossing.

$$a - a' = .04\ \ (24 + 18) + \frac{6}{12} + .10\ \ (12) = 3.38,$$

the maximum amount by which a' can be lower than a.

Since g is fixed at 3 per cent, then

$$.03\ \ (a\ I) + g'\ \ (a'\ I) = 3.38, \text{ or } g' = \frac{3.38 - .03\ \ (a\ I)}{a'\ I}.$$

The building line platform is the name given to the street area comprised between the building lines and the perpendiculars to them from the acute angles between building lines, as shown by dotted lines in Fig. 45. The curb line platform is the area between curb lines and perpendiculars to them from the acute angles of the curb lines. In a right-angled intersection these become the rectangles included between the street lines continued, and the curb lines continued across the intersection, respectively.

Two methods sometimes employed are known as the "level building line platform" and the "level curb line platform." They consist in giving the same elevation to all four corners of the building line platform or of the curb line platform. These once fixed, the rest is easy.

Example of building line platform method (Fig. 44):

Assume $S_1 = S_2 = S_3 = S_4 = 100.90$.

Then $s_1 = 100.6$		$s'_1 = 100.9$
$s_2 = 100.0$		$s'_2 = 100.9$
$s_3 = 100.0$		$s'_3 = 99.7$
$s_4 = 100.6$		$s'_4 = 99.7$

$a = 100.6$ $b = 100.9$ $d = 100.0$ $e = 99.7$ $I = 100.3$

The above is using the extreme desirable sidewalk slopes to favor the ground. If the grades are light, all sidewalks can be given a 2 per cent slope and every s will have elevation 100.6 and every s', 100.66.

Similarly using extreme slopes in the curb line platform method:

Assume $c_1 = c_2 = c_3 = c_4 = 100.30$

Then $s_1 = 100.54$	$S_1 = 101.14$	$s'_1 = 100.96$
$s_2 = 100.06$	$S_2 = 100.96$	$s'_2 = 100.96$
$s_3 = 100.06$	$S_3 = 100.06$	$s'_3 = 98.86$
$s_4 = 100.54$	$S_4 = 100.54$	$s'_4 = 99.34$

$a = 100.54$ $b = 100.96$ $d = 100.06$ $e = 99.15$ $I = 100.30$

These level platforms may be used if neither grade exceeds 3 per cent; but with steeper grades they produce conditions which too greatly depreciate the value of abutting property, make expense of grading too great, and give the objectionable appearance of sloping into the hill. To avoid this appearance the grade across an intersection should be at least one-third of the grade above it or below it, whichever is the flatter.

If it is *certain* that the paved part of the sidewalk will never extend back of a line some feet outside of the building line,

this may be substituted for the building line in the calculations, which will considerably simplify them in some cases.

Having fixed s and s' for each corner, the curb looks best if carried to the curb intersection at the grade of the center line opposite; or if the curb is curved, it takes the elevation which would be given to the same points in the sidewalk if this were continued out to the curb tangent intersection. The depth of gutter below curb remains uniform around the curve, unless it is necessary to change it in order to give the gutter a continuous slope between s and s', or unless modified by the presence of a storm water inlet or " flush " crossings.

These calculations are based on the assumption that the streets are being designed as business streets or thoroughfares, with sidewalks paved from property line to curb. If, however, the streets will always remain as residence streets with little foot traffic, the sidewalks can be elevated and terraces and retaining walls used, as described elsewhere. The roadways should then be crowned symmetrically to accommodate the traffic and kind of pavement, and crossings designed independent of the sidewalks. The sidewalks can be planned with elevations and cross-slopes which will best fit the ground and need not complicate the road grading in any way.

But if there is any chance that the streets will at any future time become business streets or thoroughfares for foot traffic, then the calculation of grades and elevations should be made as above, and they should be adopted as official; but for the present the sidewalks can be built elevated to fit the ground, with the understanding that whenever it may become necessary the city can order the abutting owners to rebuild them in accordance with the official grades and elevations.

CHAPTER III

STREET SURFACE DETAILS

Art. 11. Sidewalks, Curbs and Gutters

"Sidewalk" is used to designate either the space between the curb and property line, or the strip within these limits paved for walking. The latter is popularly called the "pavement" in many localities, a relic of the days when roadways were not paved. In this chapter sidewalk will be used to designate the space, sidewalk pavement the paved strip thereon.

The object of a sidewalk is to afford a dry, comfortable and safe way for pedestrians where they will be protected from all vehicles, horses, dirt, street drainage, and even sun and rain in certain cases. The more uneven and dirty the roadway the more necessary is a proper sidewalk. To be dry, the pavement must rapidly shed all rain water to some channel and be elevated above the roadway, and must be either non-absorptive or thoroughly underdrained and porous. To be comfortable it must be comparatively flat transversely and have little grade longitudinally; must be of sufficient width for at least two to walk abreast or pass each other; must be of even surface, smooth but not slippery, with no sudden breaks in the surface or sudden considerable changes of grade. To be safe it must be impossible for vehicles to pass onto it from the street; it must have no openings, projections or other features which may cause falls; and no projections over or at the side of pedestrians, such as signs, show cases, awnings, etc., against which they may strike in walking.

Sidewalks should also be economical in construction and maintenance. For comfort and safety, sidewalk pavements should be as nearly continuous as possible. There must, appar-

ently, be breaks at street crossings, but the line of the sidewalk should be as dry, comfortable and safe as possible between curbs of the cross streets.

Driveways across Sidewalks. Where a driveway to a private stable or garage, engine house, etc., crosses a sidewalk, either a bridge must be set from top of curb to the other side of the gutter, or this space be filled across to the haunch of the road with a pipe culvert carried through the fill, or the ground must be sloped up from the gutter to the sidewalk level inside the curb line. The first two interfere with the use of the side of the road by traffic and are liable to stoppage by dirt, leaves or snow, and are unsightly. In some cases a temporary bridge is used, consisting of two or three flat bars of heavy wrought iron bent in the form of a Z with one horizontal end about 6 in. long to rest on top of the curb, the other 2 or 3 ft. long to hold the plank bridge, and the vertical part about 2 in. high. Two-in. plank 8 ft. long are fastened to the long horizontals. These can be raised at any time for cleaning under them. Where the gutter is very deep a bridge is necessary.

In carrying an inclined driveway up from the gutter, the grade of the incline may be as steep as 1 in 6 or 8. With a 5-ft. planting strip and 6-in. curb, the sidewalk pavement will be about 8 or 9 in. above the gutter, and a slope of 1 to 7 will bring the driveway to the edge of the sidewalk pavement. The general surface of the sidewalk pavement should never be dropped to accommodate a private driveway except where the pavement is next to the curb, when this seems to be necessary. Where the pavement covers the entire sidewalk space, or a narrow one is next to the curb, it must be dropped at the driveway and the driveway and pavement may be connected by a vertical face or curb, or by a sloping surface set to an incline not steeper than 1:5; preferably the latter, in which case it is better to carry the gutter curb across the driveway but cut down or lowered so as to rise only about 1 in. above the gutter, the depression in the curb being sloped at the ends. Where the dropped driveway is in the planting strip, a curb should be set along its edge extending back

from the gutter curb, to retain the soil. It is desirable to round the intersection of gutter and driveway curb, with a radius of 18 in. to 36 in.

The pavement of a driveway must be sufficiently heavy to carry the vehicles using it, this including the entire width of sidewalk space. Cobbles are sometimes used, but concrete built like a concrete roadway pavement is becoming most common. The pavement should be sufficiently rough, or should be grooved, to afford a foothold for horses or friction for automobile tires.

Steps may be used on steep grades—say any exceeding 15 per cent—either continuous from top to bottom, or alternating with short stretches of walk having 5 to 10 per cent grade. (See Figs. 15 and 16.) Steps should be at least 5 ft. wide, and are generally provided with railings. Stone or concrete are the best materials, although brick, iron or wood are often used. With stone or concrete, iron pipe railings are most economical; with wood, wooden railings; but artistic railings of bronze are advisable where appearance is considered. The rise of the steps should be from 6 to 8 in.—$6\frac{1}{2}$ or 7 in. is probably best; the tread 10 to 15 in. wide—11 or 12 in. is probably best. An 8-in. rise and 10-in. tread is too steep for most places. If the slope exceeds 2 vertical to 3 horizontal it is better to wind the steps obliquely from side to side of the street, with platforms at the turns. Each step should have a very slight pitch toward the back and toward one end, to shed water from the end and not the front, and to reduce danger from slipping. A paved gutter should receive this water to prevent wash of the hill and undermining of the steps.

Cross-gutters. To carry roof and yard drainage across the sidewalk several plans have been adopted. (It is best to avoid this where possible by draining to the sewer, or into a cistern.) A pipe is carried under the sidewalk or above the heads of pedestrians (the latter generally on permanent awnings) to the gutter; a channel, open or closed, is constructed in the pavement surface; or the water flows over the surface of the pavement without any controlling channel. In the first, where the pipe is under the

pavement, it debouches through an opening in the curb. This is the most expensive plan, but probably the best, as there is no inconvenience whatever to pedestrians. The objections are the possibility that the pipe will freeze shut in winter, or become stopped with leaves, dirt, etc.; but if connected with the roof leader, the pressure from this will ordinarily prevent either. The pipe should be of cast iron, 3, or better 4, in. diameter and be covered with 2 in. of pavement material; and be carried of the same size and material to a point about 8 ft. above the ground, where it ends in a funnel which receives the roof water; except that if this pipe be as large or larger than the roof-water leader it may be connected directly to it a short distance above the ground.

An open channel in the pavement surface is ordinarily a slight depression about 1 or 2 in. deep and 4 to 8 in. wide, carried from the end of the rain-water leader directly across the pavement. This affords a slight inconvenience to pedestrians, and keeps from the sidewalk the yield of light rains only; but is preferable to making no provisions to prevent the roof-water from flowing over the entire walk. In some cities iron boxes are used, their tops flush with the pavement, and having sometimes loose covers at the pavement level (which are more often out of position than in it, when they are dangerous to pedestrians); sometimes a slot is carried lengthwise through the top, through which dirt enters and fills the box, the idea apparently being to afford access to the box for cleaning. Neither of these is recommended. If loose covers are used, a continuous flange or occasional lugs on them projecting an inch or more down each side of the box will prevent accidental displacement. A better plan is a box drain of iron, slightly smaller at the bottom than at the top, set in concrete so that the top shall be just flush with the pavement surface. If the box be made in 4- or 5-ft. lengths, these can easily be raised and cleared of deposits when necessary.

When *vaults*, basements, coal-bins, etc., are extended under the sidewalk, this is generally supported at the curb and

the building line only, and is called a platform walk. It is constructed of steel beams, either supporting flag-stones on two sides, or connected by brick or terra-cotta arches on which the sidewalk pavement is laid. All joints in flagstone laid as above must be made water-tight by asphalt, sulphur or calked lead. If coal holes are cut in them, a channel or groove may be cut in the flag around and about an inch from the opening and continued in a straight channel to the curb. The supporting beams may be laid transversely of the walk; but ordinarily it will be cheaper to set one or two longitudinal beams supported on piers at intervals. Instead of arches or flag-stones, several constructions have been employed, such as deeply corrugated steel plates, filled with concrete sidewalk material. Frequently these basements are lighted by " sidewalk lights," lenses or prisms of glass cemented or leaded into stout cast iron frames, which together serve as a part of the pavement. Slabs containing vault lights or sidewalk lights are also built of expanded metal and concrete and other forms of concrete-steel construction. The ordinary cast-iron plate containing round glass lenses $1\frac{1}{2}$ to 2 in. diameter is called a " bulls-eye sidewalk plate." The city should see that these platform walks are sufficiently heavy to support loaded hand trucks in addition to a load of 100 lbs. of pedestrians per sq. ft. with a factor of safety of 3. The surface should be smooth and as little slippery as possible.

Plank sidewalks raise pedestrians above mud and water, and are fairly effective in protecting from vehicles; they are cheap (in first cost) where lumber is abundant. But as ordinarily made they do not keep an even surface, and the planks quickly rot or wear out or are broken, making their use both inconvenient and dangerous; and they are not often ultimately economical. In St. Paul, inspecting and repairing 321 miles of wooden sidewalk for one year cost $39 per mile; judgments and damage suits in connection with accidents occurring on them cost $14 per mile; making the total annual cost over 1 cent per lineal foot for maintenance. Construction in the same city cost about 5 to 7 cents per sq. ft.; in Omaha, 6 to 7 cents.; in Helena, Mont.,

7 cents; in Rochester, $6\frac{1}{3}$ cents. The life will average three to six years. At five years, this gives renewal at 1 to 1.4 cents per year, and total annual cost of 1.2 to 1.6 cents per sq. ft., or 10.8 to 14.4 cents per sq. yd.

Plank walks are laid with longitudinal planks on transverse sills, or with transverse planks on longitudinal stringers. In the former construction the sills should be not more than 3 ft. apart between centers, of 4×4 or 4×6 timber, each resting upon three bricks or stones rammed into place to give firm support and properly graded, and of the exact width of the walk. The planks should break joints, and the distance between planks transversely should not exceed $\frac{1}{2}$ in. nor be less than $\frac{1}{8}$ in. Each plank should have at least one 4 in. nail in each sill for each 4 in. of width or fraction thereof. No earth should be in contact with either sill or plank.

Transverse planks should be cut with square ends to the assigned length, free from loose knots, splits, etc. The stringers should be not less than 12 ft. long and should break joints. Where the sidewalk is from 4 to 6 ft. wide three stringers should be used, equally spaced; where 6 to 9 ft. wide, four stringers; 9 to 12 ft. wide, five stringers. Stringers should rest upon firmly settled bricks or stones, not more than 6 ft. apart, if of 4×4 material. In Omaha the stringers are cut square at the ends and toe-nailed together; in Cincinnati they are joined with a 3-in. half-lap splice, spiked. The planks should be laid with a $\frac{1}{8}$ to $\frac{1}{4}$ in. air space between them, nailed to each stringer with one 4-in. nail for each 4 in. of width or fraction thereof, and overhanging each outside stringer by 4 to 6 in. In Omaha a No. 10 galvanized iron wire is fastened at each edge of the walk with a wire staple in each plank.

The walk of transverse planks is the more common. It keeps its surface better, and broken or worn out planks are replaced more readily and at less expense. Also any desired width can more readily be obtained from ordinary lumber. In St. Paul sidewalks are laid 3, 4, 6, 8, 10 and 12 ft. wide; in Rochester 3, 4 and $4\frac{2}{3}$ ft. Four and 6 ft. are probably the most common widths.

Gravel sidewalks are not adapted to streets having much travel, but are used ordinarily in parks, private grounds, and local residence streets. They should be under-drained either with tile drains or, more commonly, with cinders and broken stone or coarse gravel in a trench 6 or 8 in. deep and the width of the walk; but if the soil be sandy, 3 or 4 in. of $\frac{3}{4}$-in. stone or gravel is sufficient. This should be of such depth that after rolling (a heavy horse roller, or even a hand roller in private grounds, is suitable) the top surface is about $\frac{1}{2}$ in. below the finished surface of the walk, and crowned about 1 in. for each 3 or 4 ft. of width. On this is placed and rolled about $\frac{1}{2}$ in. of fine torpedo gravel, the grains of which are $\frac{1}{16}$ to $\frac{1}{4}$ in. diameter. A very small amount of clay is desirable in the gravel to prevent it from rolling under foot and the coarse working to the top. At all low points the foundation should be drained in some way to prevent the collection of water there.

Cinder walks may be made in the same way, care being taken to have practically no ashes among the cinders. These walks become dusty and muddy, wash badly with rain, and are more destructive of shoe leather, besides presenting a less pleasing appearance than gravel.

Crushed stone also is constructed as above. Limestone packs well, but weathers poorly, becoming muddy and dusty, and is more difficult than gravel to drain. Consequently the foundation should be quite porous, and a drain tile running lengthwise through the middle is desirable. The top, of screenings, should not be more than $\frac{1}{2}$ in. thick. Crushed blue stone and trap make fairly good walks. Granite is too rough and sharp, cutting shoe leather, but is durable.

Brick sidewalk pavements have been quite extensively used, especially where stone for flagging is not obtainable. They *can* be made quite satisfactory, but not one in a thousand is. As commonly made, of ordinary hard-burned building brick, they retain water longer than most other paving material and consequently are damp, and slippery in frosty weather; they will not keep to an even surface unless laid on concrete, or with the great-

est care on gravel; earth collects and grass grows between the joints; water passes through them to soften the foundation; for which reasons they lack in comfort and safety. They are somewhat more desirable than planks, but much less so than concrete or stone flags. As they are generally rather uneven, brick sidewalks should have a transverse rise of at least 1 in. in 2 ft.

The standard for brick pavement adopted in Pittsburgh some years ago called for placing it in an excavation 10 in. deep, in the bottom of which is placed and rammed 4 in. of gravel or cinders; on this 4 in. of sand, thoroughly rammed, damp; on this the brick. If the soil is naturally porous, 2 in. of sand may be sufficient. In this, as in all pavements, the porous foundation should not only permit water to drain through it, but should be connected with a drain or other outlet for the water. A trench in clay is little improved as a place for a pavement by placing stone in the bottom if it can stand full of water, to soften the clay or to freeze and heave the pavement. This is one of the most common errors in pavement construction. Ashes should not be used for sidewalk foundations, but steam boiler cinders free from fine ash. Black cinders (those drenched with water while hot) are best.

The bricks should be hard burned, uniform of size and with sharp angles and plane faces. In place of bricks, rectangular, square or hexagonal blocks of scoria have been used, but with little satisfaction. In constructing a brick walk a 2×4 scantling is placed along each side of the proposed walk, its top carefully set to the sidewalk grade. (The curb, if in place, may take the place of one scantling.) A template spanning the pavement space whose lower edge is 2 in. below the top of the scantling, is then drawn along these, thus surfacing the sand 2 in. below the pavement level. On this the bricks are laid, without disturbing the sand, as close together as possible. A wide board is then placed on the brick and pounded with a tamper over its entire area, the board being shifted so as to ultimately cover the entire pavement. Sand is then spread on the pavement,

to be worked into the joints by the travel. The pavement is frequently edged with a row of brick on edge along each side. The bricks are sometimes set in rows across the pavement, sometimes "herringbone." The pavement should be set about $\frac{1}{4}$ in. high to allow for settlement of the foundation, and 1 in. higher than sod on either side.

In some instances sidewalks have been paved with bricks set on edge, similar to roadway paving, arranged in the same patterns as flat brick. These are of course more expensive than flat brick pavements, requiring twice the number of brick; they keep their surface better (although not so well as other paving) but possess the other disadvantages of brick sidewalk pavement.

Baker gives the cost of labor in placing sand cushion and laying brick at 4 to $4\frac{1}{2}$ cents per sq. yd.; but cites a city in central Illinois where this cost 10 cents by city force on a large area, or 13.1 cents including excavating. Cinders, gravel, or sand will probably cost 10 to 40 cents per sq. yd.; brick 30 to 50 cents. The cost of completed pavement (contract prices) in several cities has been as follows: Reading, Pa., 79 cents per sq. yd.; Kansas City, Mo., 78 cents to 82 cents; Helena, Mont., $1.40; Atchison, Kan., 50 to 65 cents, and relaying old pavement 18 cents. At 80 cents, and assuming a life of ten years, with no expense for maintenance, the annual cost for interest and sinking fund would be about $10\frac{1}{4}$ cents per sq. yd.

Flagstones used for sidewalks are usually a fine-grained sandstone, although slate and some other stones which can be quarried in large slabs are used when more accessible and cheaper. In eastern New York state and New Jersey bluestone (a kind of sandstone) is commonly used. Granite has been used, especially in large cities, but wears smooth and slippery and is expensive in large slabs. Some limestones have given good satisfaction.

In a flagstone walk each stone should extend the entire width of the pavement when this is 5 ft. or less, and measure at least 3 ft. parallel to the street. For wider pavements the width may be made up of two or more slabs, although the larger the slabs

the more permanently smooth the pavement. A slab was laid on Broad street, Newark, N. J., some years ago 12×21 ft. 7 in., and 8 in. thick; but 16 to 25 sq. ft. and 1½ to 4 in. thick are the usual proportions. The thickness should be made greater the greater the area, the weaker the material, and the heavier the loads which are liable to be dropped or wheeled upon it. In some business districts of large cities, sidewalk stones 5 to 8 in. thick are used and their edges are cut square and serve in place of curbstones.

Flagstones should be cut with straight, square edges and laid with close joints. If there are two or more stones crosswise of the pavement, they should be laid in rows, each of a uniform width throughout and with the joint between rows a continuous line without jogs. The stones should be set on a foundation of 4 to 6 in. of sand or steam cinders well rammed. This should be a little high, and the stone be settled into it by wooden paving rammers, or by sliding the stone an inch or two out from and into its place a few times. A stone should never be raised by ramming stone chips or sand under the edges; but if too low, it should be lifted entirely and sand spread in the middle two-thirds; then it should be rammed to a firm bearing again. When first set, the pavement should be about ¼ in. high to allow for settlement of the foundation. It should be, in its final position, at least one inch higher than the sod on either side.

Tar or asphalt sidewalks were once popular and are still used in perhaps a dozen or so cities, most of them in New England. One objection to them is the difficulty of obtaining tar which will not soften in summer or crack in winter. They are generally made of a base of tar or asphalt and stone mixed as for a roadway of bituminous concrete, surfaced with a mixture of tar or asphalt with sand or screenings.

Concrete Sidewalks. These are also called cement, granolithic, artificial stone and by other names. They are by far the most popular pavements now constructed and probably the best. They are built from 2½ to 30 ft. wide, generally divided into blocks not more than 4 to 6 ft. in any dimension. Concrete has been

made into slabs and laid like flagstone, either with or without reinforcement.

Of 553 cities and towns reporting to *Municipal Journal* as to work done in 1914, 490 had laid sidewalk pavements of concrete, 31 of flagstone, 14 of brick, 12 of tar concrete (11 of these in New England), 2 of wood and 4 miscellaneous. Of these, 395 reported the thickness which they gave to concrete pavements, 274 making them 4 in. thick, 30 5 in. thick, 30 6 in. thick, 15 4½ in. thick, 10 3 in. thick, 6 3½ in. thick, and 3 5½ in. thick. Of these cities, more than half reported the cost of concrete as between 75 cents and $1.00 per sq. yd. As concrete walks should last fifteen years, this would make the annual interest and sinking fund about 7½ to 10 cents per sq. yd. The repairs to keep concrete in good surface would be less than for brick, so the total annual cost would seem to be appreciably less.

Cement walks should be laid on 2 to 6 in. of sand, gravel or clean cinders well rammed, and with provisions for draining to the gutter, sewer, or some other point at intervals of not more than 200 ft. The object of this foundation is to prevent heaving by frost, frost requiring water and therefore any construction which will keep the ground under the walk dry meets the requirements. D. B. Lutin has proposed a walk with no foundation, but with the ground surface sloping toward the center, along which a longitudinal drain is placed, the concrete being 6 in. thick at the middle and 3 in. at the edges. But this has not been adopted, so far as the author is aware.

The walk should be set about 1 in. above the ground on either side where there is sod, and 1½ in. if the ground is bare and to be seeded, because sod, in growing, raises the surface of the ground. In its permanent elevation, the sodded surface should be ½ to 1 in. lower than the edge of the sidewalk, so that the latter will be sure to drain off and the grass will not grow onto the walk. This applies to all kinds of sidewalk pavement.

The surface should never be finally floated (rubbed down) with a steel float or trowel, but a wooden float should be used for finishing the surface. It was formerly the practice to

roughen the surface by brushing it with a broom or bristle brush, or roll it with groover or dot roller which made depressions about $\frac{1}{8}$ in. deep; but these are seldom used now, the wooden float being used instead.

A tint is sometimes given the wearing surface by adding dry mineral colors to the mortar. Ultramarine is said to increase the strength of mortar, other colors to decrease it. Lamp black is probably the only color which is cheap enough for sidewalk work which will not fade. Germantown lampblack gives a bluish-gray or stone color. Baker ("Roads and Pavements") recommends adding 4 lbs. per cubic yard of sand, mix thoroughly with the sand and keep the whole wet and banked up for at least twelve hours before adding the cement. Other colors suggested for use are:

Ingredient Used	Color Obtained	Quantity per Barrel of Cement Pounds
Peroxide of manganese	Black	48
Ultramarine blue	Blue	20
Brown ochre	Brown	24
Ultramarine green	Green	24
Oxide of iron	Dull red	24
Pompeian or English red	Bright red	24
Purple iron oxide	Sandstone red	24
Violet iron oxide	Violet	24
Yellow ochre	Yellow	24
White sand, or powdered white marble, for the mortar sand	White	.....

After the wearing coat is troweled and marked it should be covered with canvas, straw, or some other substance that will prevent evaporation; and after the first or second day, should be sprinkled occasionally if the atmosphere be dry. If the atmosphere be moist, it may be sufficient to place boards over the walk to protect it from the sun, rain or other injury. (Manure as a covering on fresh concrete is said to rot it.)

For a small job, concrete may be mixed by hand on a board platform or a large plate of $\frac{1}{8}$-in. steel. The latter is tighter, preventing loss of cement and water. Rings fastened in two

corners facilitate dragging it ahead as the work progresses. *Never mix concrete on the ground.*

Small concrete mixers can be obtained, operated by hand or by small gasoline engine, which will be economical for jobs of say 1000 sq. ft. or more and generally give more thorough mixing than by hand. Thorough mixing, until the material is uniform throughout in color and appearance, is essential to the best work.

Details as to proportioning of materials and general method of construction are given in the following specifications, recommended in 1915 by a committee of the National Association of Cement Users. These provide for either one-course or two-course pavement. The opinion is becoming increasingly general that the one-course is preferable.

SPECIFICATIONS FOR PORTLAND CEMENT SIDEWALKS

Recommended by Committee of National Association of Cement Users

MATERIALS

1. The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials and adopted by this Association. (Standard No. 1.)

2. The aggregates shall be clean, coarse, hard, durable materials and shall be free from dust, soft, flat or elongated particles, loam, vegetable or other deleterious matter. In no case shall aggregate containing frost or lumps of frozen material be used.

(*a*) *Fine Aggregate.* Fine aggregate shall consist of a crushed stone which tests or experience have proved to withstand abrasion. The stone in any locality that is most satisfactory for macadam roads is suitable. It shall be graded from fine to coarse, the larger particles predominating in quantity, and passing, when dry, a screen having one-half ($\frac{1}{2}$) inch round holes, and preferably none shall pass a screen thirty (30) meshes per linear inch.

(*b*) *Coarse Aggregate.* Coarse aggregate shall consist of inert materials such as crushed stone or gravel, graded in size, retained on a screen having one-quarter ($\frac{1}{4}$) inch diameter holes and the maximum size shall be such as to pass a one and one-quarter ($1\frac{1}{4}$) inch ring.

(*c*) *Natural Mixed Aggregates.* Natural mixed aggregates shall not be used as they come from the deposit, but shall be screened and remixed to agree with the proportions specified.

3. Only clean, hard, suitable material, not exceeding four (4) inches in the largest dimension shall be used in the sub-base.*

4. Water shall be clean, free from oil, acid, alkali or vegetable matter.

5. If artificial coloring material is required, only mineral colors shall be used.

6. The reinforcing metal shall meet the requirements of the Standard Specifications for Steel Reinforcement adopted March 16, 1910, by the American Railway Engineering Association.

7. The expansion joint filler shall be a suitable elastic waterproof compound that will not become soft and run out in hot weather, nor hard and brittle and chip out in cold weather.

SUB-GRADE*

8. *Slope.* The sub-grade shall have a slope toward the curb of not less than one-half ($\frac{1}{2}$) inch per foot.

9. *Depth.** (*a*) The sub-grade shall not be less than eleven (11) inches below the finished surface of the walk.

(*b*) The sub-grade shall not be less than five (5) inches below the finished surface of the walk.

10. *Preparation.* All soft and spongy places shall be removed and all depressions filled with suitable material which shall be thoroughly compacted in layers not exceeding six (6) inches in thickness.

11. *Deep Fills.* When a fill exceeding one (1) foot in thickness is required to bring the work to grade, it shall be made in a manner satisfactory to the engineer. The top of all fills shall extend beyond the walk on each side at least one (1) foot, and the sides shall have a slope not greater than one (1) on one and one-half ($1\frac{1}{2}$).

12. When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

SUB-BASE*

13. *Width—Thickness.* On the sub-grade shall be spread a suitable material as hereinbefore stated which shall be thoroughly rolled or tamped to a surface at least five (5) inches below the finished grade of the walk.

*NOTE—When a sub-base is required, eliminate paragraph 9(*b*). When a sub-base is not required, eliminate paragraphs 3 and 9(*a*), 13 and 14. Unless paragraph 9(*a*) is eliminated, 9(*b*) is void.

On fills, the sub-base shall extend the full width of the fill and the sides shall have the same slope as the sides of the fill.

14. *Wetting.* While compacting the sub-base, the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited.

FORMS

15. *Materials.* Forms shall be free from warp and of sufficient strength to resist springing out of shape.

16. *Setting.* The forms shall be well staked or otherwise held to the established lines and grades and their upper edges shall conform to the established grade of the walk.

17. *Treatment.* All wood forms shall be thoroughly wetted and metal forms oiled before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

CONSTRUCTION

18. *Size of Slabs.* The slabs or independently divided blocks when not reinforced shall have an area of not more than thirty-six (36) square feet and shall not have any dimension greater than six (6) feet. Larger slabs shall be reinforced as hereinafter specified.

19. *Thickness of Walk.* The thickness of the walks should not be less than five (5) inches for residence districts, and not less than six (6) inches for business districts.

20. *Width and Location of Joints.* A one-half ($\frac{1}{2}$) inch expansion joint shall be provided at least once in every fifty (50) feet.

21. *Protection of Edges.* Unless protected by metal, the upper edges of the concrete shall be rounded to a radius of one-half ($\frac{1}{2}$) inch.

MEASURING AND MIXING

22. *Measuring.* The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A bag of Portland cement (94 lb. net) shall be considered one (1) cubic foot.

23. The ingredients of the concrete or mortar shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing continued until the materials are uniformly distributed and the mass is uniform in color and homogeneous.

(*a*) *Machine Mixing.* When the conditions will permit, a machine mixer of a type that insures the uniform proportioning of the materials throughout the mass, shall be used.

(*b*) *Hand Mixing.* When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until the mass is uniform in color and homogeneous.

24. *Retempering*, that is, remixing mortar or concrete that has partially hardened with additional water, will not be permitted.

Two-Course Walk

BASE

25. *Proportions.* The concrete shall be mixed in the proportion by volume of one (1) part Portland cement, two and one-half ($2\frac{1}{2}$) parts fine aggregate and five (5) parts coarse aggregate.

26. *Consistency.* The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

27. *Placing.* After mixing, the concrete shall be handled rapidly and the successive batches deposited in a continuous operation completing individual sections. Under no circumstances shall concrete be used that has partially hardened. The forms shall be filled and the concrete struck off and tamped to a surface the thickness of the wearing course below the established grade of the walk. After the concrete has been thoroughly tamped against the cross forms, they shall be removed and the material for the adjoining slab deposited so as to preserve the joint. Workmen shall not be permitted to walk on the freshly laid concrete, and if sand or dust collects on the base it shall be carefully removed before the wearing course is applied.

28. Slabs having an area of more than thirty-six (36) square feet, or having any dimension greater than six (6) feet, shall be reinforced with wire fabric or with plain or deformed bars. The cross-sectional area of metal shall amount to at least 0.041 sq. in. per lin. ft. The reinforcement shall be placed upon and slightly pressed into the concrete base immediately after the base is placed. Reinforcement shall not cross joints and shall be lapped sufficiently to develop the strength of the metal.

WEARING COURSE

29. *Proportions.* The mortar shall be mixed in the manner hereinbefore specified in the proportion by volume of one (1) part Portland cement, and not more than two (2) parts fine aggregate.

30. *Consistency.* The mortar shall be of a consistency that will not require tamping, but which can be easily spread into position.

31. *Thickness.* The wearing course of the walk in residence districts shall have a minimum thickness of three-quarter ($\frac{3}{4}$) of an inch, and in business districts a minimum thickness of one (1) inch.

32. *Placing.* The wearing course shall be placed immediately after mixing and in no case shall more than fifty (50) minutes elapse between the time the concrete for the base is mixed and the time the wearing course is placed.

33. *Finishing.* After the wearing course has been brought to the established grade, it shall be worked with a wood float in a manner that will thoroughly compact it. When required, the surface shall be troweled smooth, but excessive working with a steel trowel shall be avoided. The slab markings shall be made in the wearing course directly over the joints in the base with a tool which will completely separate the wearing course of adjacent slabs. If excessive moisture occurs on the surface, it must be taken up with a rag or mop and in no case shall dry cement or a mixture of dry cement and sand be used to absorb this moisture or to hasten the hardening. Unless protected by metal, the surface edges of all slabs shall be rounded to a radius of about one-half ($\frac{1}{2}$) inch.

34. If artificial coloring is used, it must be incorporated with the entire wearing course and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed five (5) per cent of the weight of the cement.

One-Course Walk

The general requirements of the specifications covering two-course work will apply to one-course work with the following exceptions:

35. *Proportions.* The concrete shall be mixed in the proportion of one (1) part Portland cement, two (2) parts fine aggregate and three (3) parts coarse aggregate passing a one (1) inch ring.

36. *Placing and Finishing.* The forms shall be filled, the concrete struck off and the coarse particles forced back from the surface, and the work finished in the usual way.

37. *Reinforcement.* When a single course walk is to be reinforced, the metal shall be placed in the middle of the section. The minimum amount of metal shall be as specified in Paragraph 28.

Protection

38. *Treatment.* As soon as the concrete has hardened sufficiently to prevent being pitted, the surface of the walk shall be sprinkled with clean water and kept wet for at least four (4) days. The walk shall not be opened to traffic until the engineer so directs.

39. *Temperature below 35 degrees F.* If at any time during the progress of the work the temperature is, or in the opinion of the engineer will within twenty-four (24) hours drop to thirty-five (35) deg. Fahrenheit, the water and aggregate shall be heated and precautions taken to protect the work from freezing for at least five (5) days. In no case shall concrete be deposited upon a frozen sub-grade or sub-base.

Curbs are used to protect the sidewalk pavement, lawns and trees from teams and from the water of the gutters, to hold in place both street and sidewalk pavement, and to add to the appearance of the street. Since the roadway and sidewalk are at different levels, the curb must act as a beam, the general tendency being for it to fall into the roadway. The face of the curb should have a slight batter, so that wheels will not scrape the entire face but only the bottom; but the batter should be slight, that it may be difficult for wheels to mount it. As the pavement may have a slope of 1 in 30 and the curb should make a little more than a right-angle with it, the batter should be 1 in 20 or 24—say $\frac{1}{4}$ in. in 6 in. The top of the curb should pitch slightly toward the roadway so as to drain into the gutter, about 1 in 18 or 20 from the horizontal giving good satisfaction; giving an angle of about 95° between face and top. The corner of the curb is generally rounded with a $\frac{1}{4}$ or $\frac{3}{8}$ in. radius, to prevent chipping. The height of the curb above the gutter varies from 4 to 10 in. in different places, 6 in. being the most common height.

A good curb should present a smooth, plane face which resists abrasion, and should be stout enough to receive without injury or motion the blows from wheels backed against it, and strong enough to resist the pressure from the sidewalk; and should be set to exact line and grade, and so solidly that it will maintain this position and not be disturbed by frost or in any other way.

Whenever possible the curb should maintain a uniform height above the gutter on both sides of a street through its entire length, or at least between intersecting streets, and should be exactly true to a line parallel to the street center. But at street corners it is desirable to round the curb intersection into the arc of a circle. These " radius curbs " are a necessity in busi-

ness streets. They practically increase the width of roadways at intersections where there is much turning of traffic from one street to another. Their chief disadvantages are the additional cost and the inconvenience to pedestrians using the outer side of the sidewalk; but neither of these is serious. The larger the radius the better for vehicles. But if the radius is made too long it permits vehicles to move around the corner too quickly for safety. The longer the wheel base the longer the radius required to turn a corner at even the minimum velocity; and with recent increase in use of touring cars and motor trucks with long wheel base, the necessity for long-radius curves has increased. Several large cities have adopted 20 ft. as the radius for main thoroughfares of any kind, and 6 to 12 ft. (whichever is nearest to one-tenth of the width of the wider of the intersecting streets, in New York) for minor streets of all kinds, and these are recommended. For entrances to driveways and alleys, 2 or 3 ft. is ample. In applying these radii, the length is determined by the minor street where the streets are of different importance as to roadway traffic.

Curbs should not make angles in either line or grade, as a general thing, but changes in either should be eased off with curves. (This is true of roadway also, to the grade and line of which the curb should be parallel.)

The material used, and dimensions, should be ample to resist the blows of wagon wheels and possess sufficient beam strength. The blows of wagon wheels in the business district, at freight houses, etc., will be much more severe than in the residence districts, and the curbs in the former should be of heavy sections of granite or other tough, strong material. If this is not obtainable, a very heavy concrete curb faced with a steel angle (say 4×3 in. or 6×4 in.) is perhaps the best alternative. The angle is anchored to the curb by bolts with countersunk heads, leaving no projections on the face of the curb. In some parts of the country there are hard, dense, fine-grain sandstones (such as the Medina or Berea) which are better for curbs in such localities than concrete or any other stone except granite.

Pressure from behind may be resisted by dead weight (a heavy curb resting on the pavement and sliding on it) or by acting as a cantilever. The latter is the more common, but the former has some arguments in its favor. In some cases the curb is really but the edge or vertical face of the sidewalk, this being most common when the latter is a heavy granite or other stone 4 to 6 in. thick. These are found in the warehouse districts of some large cities. Or where a concrete sidewalk is in contact with the curb, the two may be poured as a monolith; in which case it is probably best to have the curb rest on and free to slide on the pavement foundation, if there be one.

Where the curb extends below the pavement foundation, this acts as a fulcrum. The bottom of the curb should be firmly anchored to resist the pressure against the top, and the curb be strong enough to resist this pressure as a beam. A curb pushed forward, overhanging the gutter, is objectionable as to both appearance and usefulness. Where there is a concrete sidewalk continuous from building to curb, its expansion may bring considerable pressure against the latter, pushing it forward or, failing this, causing the crushing or bulging of the sidewalk. Some use expansion joints between sidewalk and curb and even between the several sidewalk blocks. Others carry the sidewalk over the top of the curb (which is set low), ending it flush with the face of the curb; but this does not look well and the edge of the sidewalk is apt to chip and break. The author thinks that sufficient consideration has not been given to the idea of resting the curb on the foundation of the roadway pavement or the gutter, which is continued under the curb with a smooth surface and coated with tar where the curb rests on it. The curb is then made integral with the outer sidewalk blocks, or tied to them by reinforcement bars.

To prevent or diminish the pressure exerted by frost in the earth behind a curb, it is desirable to lay a 2 in. or 3 in. drain behind and a little lower than the bottom of the curb, gravel or broken stone being filled around the drain and carried up, for 2 to 4 in. back from the curb, to within 3 or 4 in. of the surface.

This drain should discharge into a sewer or other outlet at the low points. The sidewalk foundation, if it does not extend to the curb, can with advantage be drained into this drain at intervals. In a porous sandy or gravelly soil a curb drain is unnecessary.

The greatest trouble with distortion of curbs is found where a concrete sidewalk abuts against the curb at a street crossing. Some find the use of bituminous expansion joints between the several blocks or slabs for some distance back from the crossing prevents this. Another plan is to make the curb and sidewalk monolithic at the crossing, the curb being merely the end of the sidewalk, which rests on the gutter or roadway pavement and slides on it, and may be cut back to line by chisel and hammer-dressed if it should push forward. Another plan is to carry the sidewalk over the top of the curb (made low for this purpose) so that it can slide forward without disturbing the curb; being cut back when necessary.

Another plan, used successfully by H. W. Hatton and shown in Fig. 47, resists the pressure by a heavy, reinforced corner piece of combined sidewalk and curb abutting against the roadway pavement

Concrete curbs are now the most common of all materials, and if well made give good service in residence districts, and in others where heavy loads are not backed against them. Of 487 cities reporting to *Municipal Journal* the amounts of curb constructed during 1914, 417 reported concrete curbs, 21 granite, 7 sandstone, 3 limestone, 35 "stone," and 4 reported wood. Thirty cities laid combined concrete curbs and gutters. The curbs were made 4 to 0 in. wide, the majority being 6 in.; and 16 to 20 in. deep. In the case of combined curb and gutter, the curb commonly extends only to the under side of the gutter.

To prevent chipping at the corner of the curb (where it is most liable to occur) a steel bar of special form is frequently set here, anchored into the concrete. There are several such bars on the market. Their use is recommended in business districts. Forms for concrete curbs are made of wood or steel;

the latter may be purchased in assorted lengths and adapted to any height and width of curb. The wooden forms are generally

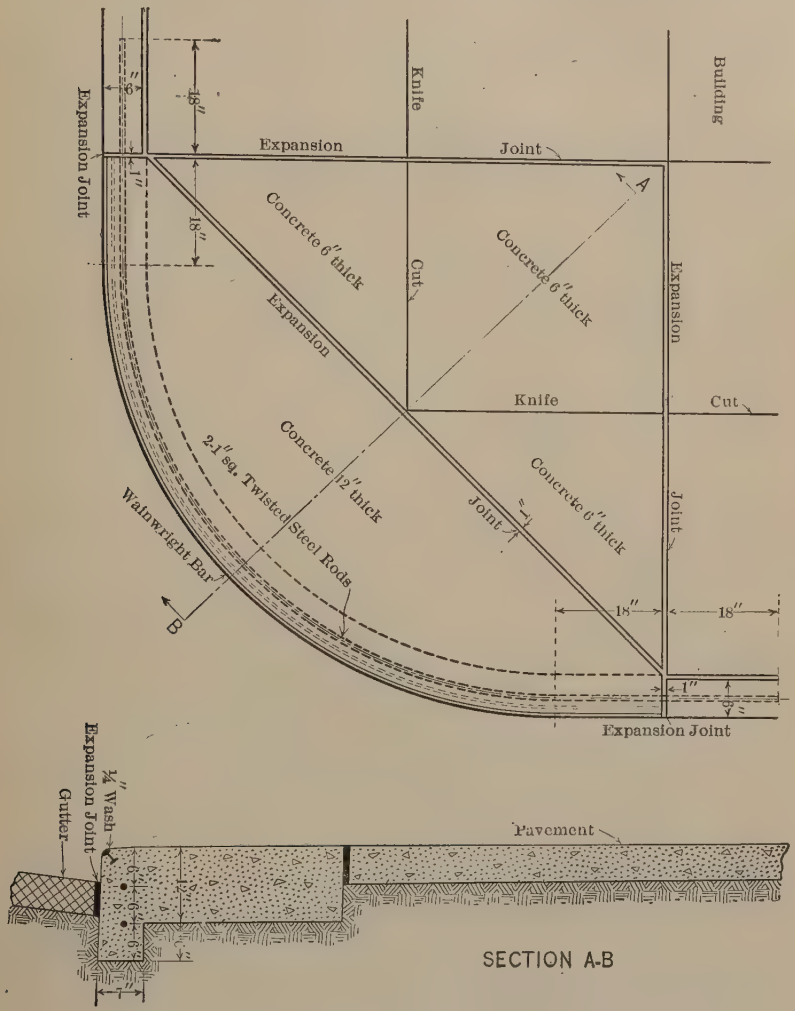


FIG. 47.—Heavy Corner of Concrete Sidewalk, to Resist Expansion.

of battened $1\frac{1}{2}$ or 2 in. plank for the front and rear faces and are held in place by stakes or iron pins driven on the outside and about 3 ft. apart. The front and rear forms are kept the proper

distance apart by partitions of wood or thin steel placed about 5 ft. apart. They must be tested carefully for grade, batter of face and pitch of top surface, and firmly fastened in position. (Clamps across the top to keep the forms from spreading apart are desirable.) The curb is generally made in sections about 5 ft. long, the joints between which are made by withdrawing the thin steel partitions when initial set has taken place, or by making alternate sections first, and, when these have set, removing the partitions and making the remaining sections.

Concrete, mixed 1 : 2 : 3 to 1 : $2\frac{1}{2}$: 5, is tamped in the forms and the top struck off and finished with a float and the edge rounded with an edging tool. While the concrete is being placed, a spade or trowel should be passed between form and concrete to force back the stone and leave only mortar on the face. Or a board $\frac{7}{8}$ to 1 in. thick is placed against the face form before the concrete is placed in the form; and after the concrete has been tamped the board is removed, and the space at once filled with mortar which is tamped thoroughly, 1 in. of mortar being placed on top of the curb also. The former is less expensive and, we believe, makes a more durable curb.

As soon as the mortar has taken its initial set, the form is removed and the exposed surfaces firmly troweled.

Assuming the average thickness of a curb to be $\frac{1}{2}$ in. greater than the top width, and a 1 in. wearing surface of mortar on top and for 7 in. down the face, the quantities of materials given in table XVIII are required per lineal foot of curb. No allowance for waste and other loss, which may be more than 5 per cent and is seldom less than 2 per cent.

Stone curbs of bluestone (a fine-grain sandstone), Berea and Medina and similar sandstones, and some limestones are satisfactory. But many limestones and all slates and shales weather and split, and are very unsatisfactory.

Stone curbs are generally 4 to 8 in. thick, 6 in. being most common; and 16 to 24 in. deep, the former being sufficient only when bedded in concrete, or where there is no frost, the latter ample in ordinary localities when thoroughly bedded in broken

stone; $2\frac{1}{2}$ to 3 times the height of the face of the curb being a good rule for the depth when it is set in concrete. The length of the curb-stones should be not less than 3 ft., and not more than 8 ft.; 5 to 8 ft. is the most satisfactory length. On a residence street a stone 5 in. thick on top and showing a 6-in. face is satisfactory in appearance and use. For business streets, or where heavy wagons back against the curb, 8 in. thickness is better, and the curb face is frequently made only $4\frac{1}{2}$ or 5 in. high.

Table XVIII

AMOUNTS OF MATERIALS FOR CONCRETE CURBS

CURB 4 INCHES WIDE ON TOP AND 16 INCHES DEEP

FOR EACH INCH ADDITIONAL THICKNESS INCREASE THE CONCRETE MATERIALS BY $\frac{2}{7}$. FOR EACH INCH ADDITIONAL DEPTH INCREASE THEM BY $\frac{1}{12}$

	Concrete, Proportioned		
	1 : 2 : 4	1 : 3 : 6	1 : 3 : 8
Broken stone	0.0140 cu. yds.	0.0146 cu. yds.	0.0160 cu. yds.
Sand	0.0070 cu. yds.	0.0073 cu. yds.	0.0060 cu. yds.
Cement	0.0220 bbl.	0.0150 bbl.	0.0121 bbl.
	Mortar, Proportioned		
	1 : 1	1 : $1\frac{1}{2}$	1 : 2
Sand	0.0016 cu. yds.	0.0020 cu. yds.	0.0022 cu. yds.
Cement	0.0113 bbl.	0.0092 bbl.	0.0078 bbl.

The greatest difficulty with stone curbing is to keep it in line, and this is almost entirely a matter of setting it properly. The best practice is to bed the curb in concrete, having 6 in. under, in front of and behind, the curb and carried up to within 4 to 6 in. of the surface, both in front and behind; this concrete being joined to the concrete pavement foundation, where there is any. If the soil is retentive of moisture it is desirable to place a small—say 3 in.— tile drain under the back face of the concrete, surrounded by 3 in. of gravel on all sides. In open soil this is unnecessary. In setting the stone, the concrete is placed in

the trench somewhat higher than the bottom of the stone is to be, and the stone is pounded down to just the right grade with wooden rammers; after which concrete is rammed along the front and back faces. The stone should be lifted by curb-tongs, or by hand and dropped onto the concrete, not slid in by crow-bars, carrying considerable dirt onto the concrete with it.

Where concrete is not used, the stone should be set in broken stone, gravel or sand, (the first being the best), placed in the same way as concrete. Where the soil is natural sand or gravel, no other material is used in most instances, unless where a concrete pavement foundation is laid, when concrete should be used under the curb also; but with other soils, curbs should never be bedded in the natural soil only.

The face of the stone to a point 1 in. beneath the surface of the roadway, should be dressed to a smooth surface, as should the top also, by "axing," "hammer dressing," "peen-hammer finishing," or machine dressing, depending upon the nature of the stone and the pavement. On an asphalted street the face should be very smooth, for appearance sake; while on a stone-block street a rougher face looks better. A fine-grain sandstone should be smooth, while granite looks well somewhat rough. The back of the stone should be at least point-dressed for 3 to 6 in. down from the top, and roughly hammer-dressed the rest of the way. The top corners are often left sharp, but it is better to round the front corner to a radius of $\frac{1}{4}$ in. to 1 in. to prevent chipping. (In Rochester and some other cities the back corner is rounded also.) The ends of the stone should be cut square and the joints dressed to a plane normal to the face of the curb for at least 12 in. down from the top. The stone should be full depth throughout, and the bottom not more than 6 in. shorter than the top, and parallel to the top; and the stone should be at no point thinner than the top width.

The amount of concrete or broken stone required for setting curbs is about one cubic yard for 25 ft. of 16-in. curb, or for 18 ft. of 20-in. curb.

Brick curbs are used in private grounds; very seldom in streets. They are made by arranging the bricks in rows, longest dimension vertical and sides touching, about 3 in. of brick

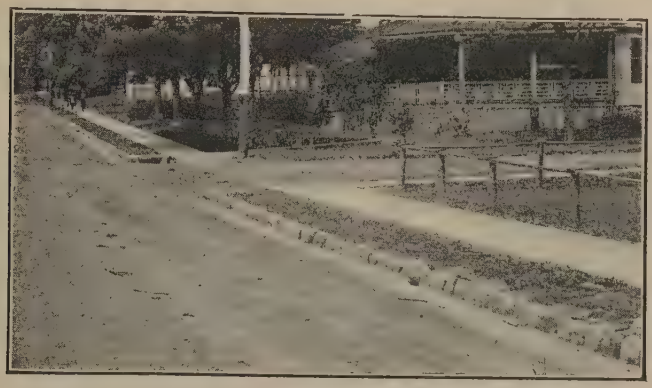


FIG. 48.—Curb Made of Cobble Stones.

being above ground and 5 in. below; sand and gravel being packed under and around them. For ornament, the brick are sometimes set with their sides making an angle of 45° with the vertical, the top then having a saw-tooth appearance.

FIG. 49.—Curb Made of Small Flat Stones.

Flat stones as large as, or a little larger than, bricks are sometimes used for curbs, set nearly vertical or leaning 30° or even 45° back from the vertical. They should be buried at least half their depth in the ground if vertical; less if inclined. They

are suitable only for dirt, gravel or broken stone roads and in connection with stone or cobble gutters.

Wooden curbs are made by setting plank on edge and holding them in position by stakes driven along the outside face 5 or 6 ft. apart. They are used where the soil is a loose sand, to protect the sidewalk from vehicles, and to a certain extent in other localities where wood is the only available material. They decay quickly and are ultimately very expensive if kept in repair.

To set curb stones (or any curbs, in fact), a common method is to drive stakes at intervals of say 20 ft., the top of the stake being at curb grade or an even 1 ft. or 2 ft. above it, and a fixed distance, say 3 ft., from the curb (face) line. After the trench has been dug, another stake is set opposite each of these (by measuring and leveling across from it) so that its top is at exact grade and line of curb. ($2 \times 4 \times 30$ in. is a good size for these stakes.) Then a cord stretched tightly from one stake (or the curb already set) to the next stake gives the line, to which the edge of the curbstone is brought and held while the stone is being fixed in position by concrete or earth fill. In making concrete curbs, the face forms may rest against these line stakes, which stakes are left in until each in turn is reached by the concrete placed, when it is removed.

Another method is to drive the stakes on the offset line, as before, but with their tops practically flush with the ground, and take the elevation of each stake. The curb setter is then given a set of notes telling the distance the curb is to be set above or below each stake. By this method the stakes serve for both preliminary grading and finished work; they are not liable to be disturbed; they may be driven when making the preliminary survey, and levels taken on them and used for plotting the profile and planning the street grade. Twenty-five out of 41 Iowa engineers questioned by Theo. S. Delay, city engineer of Creston, considered this the easiest and quickest method.

The curb grade elevations on the stakes can be set most rapidly, for such distance as the grade is uniform, by " plunging." A level (or transit) is set over a graded stake at one end of the

grade, and the target set on the leveling rod to read the distance the telescope line of sight is above the stake. (This can be measured directly by holding the rod on the grade stake and almost touching the telescope.) With the target clamped, the rod is then held on the grade stake at the other end of this continuous grade and the telescope plunged until the horizontal hair is on the target line. Then if the rod is held on any intermediate stake and moved vertically until the hair is on the target, the bottom of the rod is at grade.

Gutters should be used on dirt or macadam streets when the grade exceeds 2 per cent, and are desirable on all grades. On such streets cobble or stone block gutters are preferable to concrete, which will not give at all, and consequently is almost sure to cause a rut along the edge. No special material is now used with asphalt, brick, wood block, bituminous concrete or other material which is not washed out by water, when there is a curb and such pavement is carried to the curb; except that concrete curb and gutter are sometimes used, especially where they are built some time before the pavement is laid. The author, however, does not believe that any solid gutter should be laid unless the pavement adjoining is equally solid and non-erodable, and then the same material as the pavement is best. The reason is that erosion and wheel wear are almost sure to produce a rut or small gully in the softer material along the edge of the harder, after which the run-off from the roadway will not flow onto the gutter, but will follow the rut and increase the wash. On a dirt or macadam road a cobble gutter will be settled by wagon wheels along the edge as the road wears down, and the slight depressions between stones will permit the water to flow onto the gutter. A well-laid cobble gutter will carry off water fairly well, although not permitting as rapid flow as a concrete or brick one.

A construction which has proved successful where the gutter is to carry much water is to make it of concrete, 3 to 6 in. higher at the outer edge than at the curb, and set along the edge a strip of cobble stones 8 to 12 in. wide and pitched sharply toward

the concrete gutter. The cobble stones can then settle with the road (or be settled by ramming) and still the water drain into the gutter.

Concrete gutters are used successfully with brick, stone or other pavements which are as hard as the concrete; although even with these the longitudinal joint is apt to wear into a rut, as is the case with all longitudinal joints in roadway pavements. Concrete gutters, and most others as well, are generally made of a width between 12 and 36 in., much the most common width being 18 in.

Stone flags or slabs are often used for gutters in connection with macadam roads. They should be sufficiently thick and strong to prevent breaking by vehicles, and should be well bedded in gravel, cinders or sand, and the joints filled with cement. They are smoother than cobble, but are apt to break or cause ruts along the edge. Generally two rows of stones are laid, each row 9 to 12 in. wide and the stones 18 to 30 in. long; or a single row of 12-in. stones with an edge of cobble stones about 6 in. wide and set a $\frac{1}{2}$-in. or so higher than the flat stones.

Cobble gutters should be made of stones not more than 6 or 8 in. in diameter and 2 to 4 in. thick; smaller than this is better, but more expensive to lay, as each stone must be set by hand. They are set on edge, close together, bedded in about 6 in. of well rammed gravel, and thoroughly rammed to as nearly a uniform surface as possible. If made of all sizes of stones, set on the natural soil or with only an inch or two of sand under them, they soon work loose or out of surface. A cobble gutter should be between $1\frac{1}{2}$ and 3 ft. wide and the edge next the curb be 3 to 5 in. lower than the outer edge. Ordinarily each stone is set with its longer thickness parallel to the curb; but on steep slopes the position normal to this is preferable, as it retards the flow and reduces erosion between joints.

The disadvantages of cobble gutters are their roughness, retarding the flow of water; the liability that weeds and grass will grow between the stones; the difficulty of cleaning dirt from them; and the possibility that the stones along the edge will be

worked loose by wheels or the hoofs of horses standing at the curb. Unless carefully laid to avoid it, there may be a ragged appearance about a cobble gutter which some object to. They may be brought to approximately a uniform surface by placing a plank about 8 in. wide by 4 ft. long on top of the stones after they are set and pounding it with a rammer. The growing of grass in the joints may be prevented by filling them with tar; which makes a smoother channel for water also.

In some towns and suburban streets where there are no curbs, a cheap and satisfactory construction is secured by continuing the cobble stones toward the sidewalk with an upward slope in place of a curb, the slope being from $1\frac{1}{2}$ to 3 horizontal to 1 vertical. Or large cobbles or field stone 8 to 12 in. diameter may be set in contact along the curb line to serve as a curb. These constructions are quite effective where an air of rusticity is desired.

Brick gutters are customarily laid on a concrete foundation, and should always be so laid if the roadway pavement is on concrete. The joints should be filled with cement or bituminous filler. A number of cities have used brick gutters on asphalt streets because of the fear that water standing in the gutters would " rot " the asphalt; but this practice has been generally discontinued, as water is not believed to seriously affect modern asphalt pavements, well made.

Some lay brick in gutters parallel to the curb, others lay them normal, and a few have advocated laying them at an angle of 45°. The second plan is the more common. The first perhaps offers less resistance to flowing water, but wears more from traffic wheels. The advantage claimed for the diagonal method is that it prevents a rut wearing along the edge of the curb, since the edge is saw-toothed, and prevents wear from traffic, since no joints are parallel to the curb. It is generally found, however, that this and also toothing by allowing alternate bricks or stones to project into the asphalt or macadam pavement, say 4 in., are not desirable, since it is almost impossible to properly compact the asphalt or macadam between the teeth.

Sod gutters are occasionally used where there is little water to be carried, the sod being an extension of the parking strip to the edge of the roadway. They are suitable for parks, but hardly for streets. Unless kept trimmed, the edge of the sod becomes uneven, is cut up by wheels and is unsightly.

On steep grades a rough gutter is an advantage, and cobbles or flat stones set on edge in concrete may be used to reduce the velocity of flowing water. Except in such cases, and especially on flat grades, gutters should be given as uniform a grade as possible, with no depressions to hold water. In front of

FIG. 50.—Gutter Treatment at Storm Water Inlet.

sewer inlets, however, the gutter should be dropped about 2 in. to direct the water into the inlet, prevent its backing up onto the roadway, and to afford a higher inlet opening without raising the curb for that purpose. This drop may be even 4 or 5 in. and the slope to it begin 8 or 10 ft. from the inlet, if large volumes of water reach this point or the grade is steep. If the gutter grade is steep, a sudden rise or hump may be placed in the gutter just below the inlet to hold the water to insure its entering the inlet.

In extreme cases of steep grade and large volume of water, a combined curb and gutter inlet, the latter quite long, with a hump below it, may be advisable. Where much water is to

be carried, gutters of brick or concrete have been used $2\frac{1}{2}$ or 3 ft. wide and dished 5 to 10 in. In such cases the water should be diverted to the storm sewer (where there is one) at short intervals, using gutter inlets. These may be of cast iron; or of steel bars on edge set crosswise of the gutter, the bars being $\frac{1}{4}$ to $\frac{3}{8}$ in. thick and 1 to 2 in. deep, spaced about $\frac{3}{4}$ in. apart and fastened in a rectangular iron frame. Gutter inlets should be calculated to carry any wheel load which would probably use the street. (See also Art. 12).

Gutter Culverts. Where there is no sewer inlet or other provision for removing water from a gutter at a street crossing, the water must be carried across one or both of the roadways in some way. The simplest is to carry the gutter as such across the roadway; but this is unpleasant and even dangerous for vehicles, especially if there is a steep grade crossing it, and is to be avoided where the amount of traffic warrants the expense. No thoroughfare should be crossed by such open gutters. There is no really satisfactory method of solving the problem except by a sewer, which is one of the strong arguments for storm sewers in a city.

Perhaps the most common substitute for the open crossing is a culvert of cast iron pipe. Vitrified or cement pipe may be used if they can be buried deep enough to protect them from crushing, which is seldom possible or advisable. If the curb were 6 inches high and the roadway level with its top, and the gutter carried through at a uniform grade, no larger than a 4-in. pipe could be used, and even then the bell would rise to the surface. But nothing smaller than an 8-in. pipe should be used, because of the difficulty of keeping such culverts clean of dirt, stones, sticks and ice; and some claim that 12 in. is the minimum satisfactory size. If we assume a 10-in. pipe, the top of the bell will be 12 inches above the invert. An inch and a half could be saved by using wrought iron pipe, and such pipe (generally galvanized and sometimes corrugated) is used in some cases. The top of the bell should be covered with at least 1 in. of paving material, which gives 13 in. from roadway sur-

face to pipe invert. This means that either the roadway must be raised higher than the curb at such a crossing, or the gutter must be lowered for some distance at each end of the culvert, and continued low below the culvert until its grade (which must be descending throughout) runs into that of the street. A conbination of the two is often desirable; but if the grade of the street is flat the former alone may be possible; while if it is steep, the latter can be used alone to advantage. If the deep gutter is used, bridge stones across the gutter should be used above and below the culvert to avoid the high step at the crossing; or the pipe may be continued under the crossings; but the

FIG. 51.—Culvert in Deep Gutter. Should be guarded at wing wall.

former is preferable, since every foot added to the pipe increases the difficulty of keeping it free from deposits. (An engineer in a northern city lays a 1-in. w.i. pipe in the bottom of a gutter culvert, and blows steam or hot water through it whenever the the latter freezes shut.) The deep gutters at the ends of such a culvert are dangerous to vehicles, and should be guarded with posts, a stone wall, row of large stones or a low gas-pipe railing. Gratings are never, it is thought, successful in front of a culvert, since they are almost sure to become stopped with leaves, paper, etc.

Where there is no curb on a street and the traffic is light and roadway wide, deep gutters are sometimes used, even two

or three feet below the roadway, and the culverts under crossings are of concrete, or brick or stone arches. But such deep gutters are very objectionable in a city and are not recommended.

Box culverts with iron tops flush with the street surface have several advantages over pipes, among these being the possibility of cleaning them out by raising the covers, and of making them shallow but with ample capacity. The bottom should be smooth (concrete floated smooth is probably best), the side walls built of smooth concrete or brick, and the top a cast iron plate with projections adapted to give a foothold to horses. Some cities use, instead of masonry, a cast iron trough with removable covers. The covers must be so designed as to be strong enough to carry any load coming on them, and not to move from their position unless intentionally raised. Nothing could be much more dangerous to traffic than one of these culverts with the cover loose or broken. It is well to have one or two standard widths of culvert so that, by keeping a few extra covers in stock, one will be on hand for immediately replacing a broken one of either size. As the center plates of a culvert become worn smooth under traffic, they may be exchanged with the end plates which are less worn.

Four feet is about the maximum width for such a culvert, as a cover sufficiently strong to span a wider one is excessive in cost. Twelve to 30 in. is about the ordinary range of width, and 6 to 12 in. the range of depth. The covers are generally from 1 to 2 in. thick, not including the projections for roughening the top surface, which should be about $\frac{1}{4}$ in. high. Concrete walls of the culvert should be about three-quarters as thick as high, and the bottom 4 to 6 in. thick, depending on the width. A cast iron trough, if used, is best set on a bed of soft concrete on a well-rammed foundation, to give it continuous support throughout. The plates will generally be carried continuous across the line of the sidewalk to serve as bridge plates for foot traffic, but lighter ones may be used there, and without the roughening provided for horse traffic.

The latter plates, when worn smooth, can be used for this purpose.

Such a culvert 80 ft. long with a width of 4 ft. cost, in Memphis, Tenn., about $590, the iron plates costing $528 of this; and the city engineer, J. H. Weatherford, estimates that a storm sewer could be built for less than the cost of furnishing such culverts at every street intersection. The smallest culvert (8×12 in.) cost from $75 to $100 only, however.

The cost of maintenance of these is considerable, especially as the iron covers wear smooth very quickly, and must be renewed

FIG. 52.—Four-foot Box Culvert, Iron Top, Memphis, Tenn.

frequently; and for this reason covers of reinforced concrete instead of iron are perhaps preferable. But the concrete covers must be thicker than the iron, and therefore the gutters must be made deeper.

A disadvantage of the ordinary culvert is that the deep gutter renders useless for traffic 2 to 4 ft. of the street width at the corner, where the use of the full width is most important. To remove this objection, Memphis uses the concealed culvert, which is built back of the curb, under the sidewalk and street crossing, the inlet and outlet to the culvert being in the face of the curb. A similar plan is used for avoiding the necessity for bridge stone, a culvert cutting diagonally across a corner around which the gutter water would naturally flow, thus making it possible for

teams to turn close to the curb, or permitting flush crossings if desired.

If lowering the gutter near the ends of a culvert will leave the curb with insufficient support, the gutter pavement can be sloped down from the curb, thus making the bottom of the gutter lower than the intersection of pavement and curb, and leaving

FIG. 53.—Curb Supported by Gutter Slope, Baltimore, Md.

the curb supported up to its regular height by the pavement. The slope from curb to gutter can be made about 2 or 3 to 1. This removes the gutter several inches from the curb, which further reduces the effective width of the roadway at the corner; but this can be prevented by beginning the corner curve of the curb well back—using a long radius for it. (The same method of supporting curb has been used in Balitmore when the roadway grade was lowered after sidewalk and curb had been set. This

serves for a residence street; but for a business street the stepped curb is preferable.)

Art. 12. Minor Street Details

Street Crossings. These are conveniences for pedestrians, to furnish a smooth and dry path across the roadway, and are often raised at the curb lines to avoid the step down from curb to roadway and stepping into water when the gutters are running full. Where a pavement is hard and smooth, like asphalt, brick or wood block, no special crossing is needed. Where it is hard but uneven, like rough stone bock, they are sometimes used, sometimes not. For streets likely to be wet and muddy, like dirt or water-bound macadam, they are generally provided and are elevated an inch or two above the general grade of the roadway except at the middle 10 ft. or so; but on city streets which can be and presumably are kept clean, this elevation is not necessary. Crossings should be placed in the direct line of pedestrian travel, even though this is not normal to the curb. They should be at least 5 ft. in total width, and more if on the line of a thorofare.

The step at the curb is avoided either by raising the crossing above the road level for a few feet out from each curb, or by using bridge-stones, or by both. If the crossing is carried practically level with the curb and continued to contact with the curb, it is called a "flush crossing." There should be a drop of an inch or more at the curb to prevent street water from flowing onto the sidewalk and to indicate the limits of the roadway to vehicle drivers. In a number of cities this elevation of roadway at curb is continued entirely around the corner from one crossing to the other. In fact, this is necessary unless a storm water inlet be placed at the curb corner, otherwise water would stand in the depression here. Where flush crossings are used an inlet must be placed just beyond the crossing (near the street line continued) wherever the gutter slopes toward this crossing.

A more common method is to raise the crossing, as above, but carry the gutter through it so that water may follow around the

corner if the grades require this, or to an inlet at the corner. The end of the crossing is then a vertical face 12 to 36 in. from the curb, which is generally formed of a piece of light curbstone or a concrete curb. This gutter may be left open, to be stepped across; or a bridge of stone or iron be used, one end resting upon the crossing curb and the other upon the sidewalk curb cut down to receive it.

These raised crossings are a convenience to pedestrians, but the reverse to vehicles, since the latter wish to keep close to the curb in turning a corner, and the crossings introduce near the

FIG. 54.—Corner Inlet and Iron Gutter Bridges, Savannah, Ga.

curb two 3-in. to 6-in. humps (or one wide one). Where the gutter is carried through a crossing, the wheels may enter the gutter and jam, if there is no bridge; or, if there is one, may strike the bridgestone or plate and break it or the wheel or both. In the case of a flush crossing, the vehicle may ride onto the sidewalk. If the vehicles keep 5 to 10 ft. from the curb to avoid these several objections, the effective area of the roadway is reduced by that amount. It is the case, we believe, that the use of flush crossings is most common in cities which have very wide (uneconomically wide) roadways. With a 4-in. or 5-in. curb the step is objectionable only to those pushing baby-carriages. (Bicycles, wheelbarrows, etc., have no right to use the sidewalk.) In busy

city streets with a width of roadway adapted to the traffic, raised crossings are a great obstruction to vehicles.

Where a crossing is raised, the roadway on each side should slope up to it very gradually—at least as flat as 1 : 15 or 1 : 20; and the slope should have an ogee or reversed curve form. If the crossing is in a macadam or dirt road it is well to protect it along each side by a row 10 to 20 in. wide of small stones (cobbles). These serve as a transition from the less solid pavement to the more solid crossing and prevent or retard the formation of holes along the edges of the latter or in the surface of the former.

Crossings are most commonly made of stones 15 to 18 in. wide, 3 to 5 ft. long and 4 to 6 in. thick, laid lengthwise of the crossing in two or three rows; of brick, or of concrete. In some southern cities with clay streets, into which wheels sink a foot or more in wet weather, a continuous crossing would absolutely prevent traffic across it, and here a common practice is to use stepping stones—generally large flat stones set on edge deep into the ground and at intervals of 18 in. to 2 ft., between which wheels may pass.

In some cities the end joints of crossing stones are beveled, making about 60° with the sides, the joint pointing approximately toward the center of the roadway intersection; the object being that vehicle wheels may cross the joints in turning a corner rather than travel in the joints, the former producing much less wear. The several rows of crossing stones are generally spaced 6 or 8 in. apart and the space between filled with small cobble stones. Bluestone and other hard sandstones and granite are the most satisfactory for crossing stones. The top surface of the stone should not vary more than $\frac{1}{4}$ in. from a plane at any point, and the joints should be perpendicular to the face for the full depth of the stone.

A brick crossing has proved satisfactory when made of the best paving brick set on a 6 in. concrete foundation; or 6 to 8 in. of steam cinders or gravel, wet and thoroughly rammed, may be substituted for the concrete. The crossing, if on a macadam,

gravel or dirt road, should be 1 to 2 in. higher in the middle than at the edges.

Crossings are also made of concrete laid in the same way as a concrete roadway, crowned slightly along the center line of the crossing as in the case of brick crossings.

Where a stone or concrete crossing, or one of brick on a concrete base, is used with a dirt, gravel or macadam road, it is desirable, as stated above, to pave with small cobble stones a strip 10 to 20 in. wide along each side. The cobble stones should be set in steam cinders or gravel and well rammed with a paving rammer. Crossing stones also should be set in cinders or gravel and this material tamped solidly under both sides of each stone, after which the stone should be firmly settled in place by pounding with a wooden rammer. (This is made of a stick of oak about 8 in. diameter and 4 ft. high, the bottom end round and with a heavy iron band shrunk on, and two sticks of hickory or other suitable wood driven as handles into opposite sides of the rammer near the upper end, one about 4 to 6 in. higher than the other.)

It may be said here that this use of small cobbles is advantageous around manhole heads, along railway tracks, and wherever a solid structure comes in contact with an easily rutted or abraded road surface.

Isles of Safety. Where a thoroughfare roadway is quite wide and is crossed by considerable numbers of pedestrians, and especially where there is extreme width and confusion of traffic, as at an oblique intersection or one where more than two streets cross, an isle of safety at the crossing is a safeguard to pedestrians. This is generally a raised platform, protected from vehicles by a curb, together with posts of stone or iron in some cases; or it may be on a level with and a part of the roadway surrounded by posts 4 to 10 ft. apart. If there is a trolley line through the street it is well to place an isle of safety about 2 ft. from each track on the right hand side, so that it may serve as a landing platform for passengers. In shape an isle of safety is generally a narrow rectangle or oval in plan, from 3 to 6 or 8 ft. wide, and

FIG. 55.—Roadway Widened around Isles of Safety and Trolley Waiting Platforms.

of any length, raised 6 or 8 in. above the road surface. A light on a tall standard in the middle of the isle, or at each end of a long one, is desirable. A low post at each corner serves to

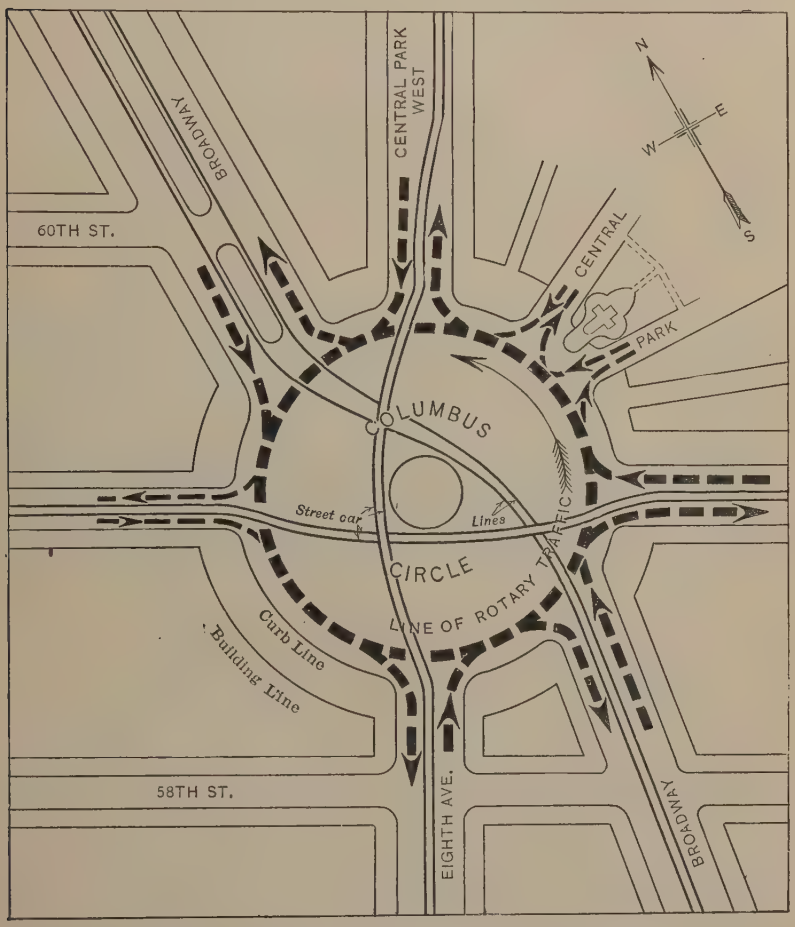


FIG. 56.—Rotary Traffic at Columbus Circle, New York.

announce to drivers the presence and location of the isle. The best location for an isle of safety is just at the edge of the crossing strip (toward the center of the block) so as not to hinder those who would cross without using it.

These structures, occupying part of the roadway width, interfere with vehicle traffic, and in this respect are objectionable unless the roadway is of unnecessary width elsewhere. This is sometimes remedied by widening the roadway opposite the isle of safety by reducing the parkway or sidewalk width. (See Fig. 55, where the isles of safety are really waiting platforms for the trolley line.) In some instances safety strips or zones are created temporarily by use of portable standards connected by ropes. This is a matter of traffic regulation rather than engineering; but indicates the possible desirability of an isle of safety there.

Traffic circles at intersections of busy thoroughfares have been recommended and tried—not always with favorable results. The idea is to place a circular island at the center of the roadway intersections, and require every vehicle to travel by or around it to the right, whatever street it enters the intersection from or leaves it through. Such a circle works very satisfactorily at Columbus Circle, New York City. (See Fig. 56.)

Automobile Parking. The crowding of the curbs of business streets with standing automobiles is a hindrance to traffic and a disadvantage to merchants. To prevent this, some place must be available for "parking" such vehicles, convenient to the business center. This may be along the curb of a parkway or park; in the center of a street which is wider than traffic requires; at the triangular "deadwater" at the junction of two streets meeting at an acute angle. If no such spot is available, a side street, just off the thoroughfare, may be made a one-way street and one side used for parking automobiles. (St. Louis and Boston have adopted the last plan in some instances.) Wherever the parking be, it should be set off by posts, curbs, or at least a line painted on the pavement, to prevent general traffic crossing it. In Marshalltown, Ia., on a side street just off the business center, a strip 16 ft. wide and 200 ft. long is provided, guarded by three oval platforms, 8×16 ft., surrounded by curbs, one at each end of the strip and one in the middle, with an electrolier in each. In other places 6-in. or 8-in. curbs are set across the

strip at intervals of about 9 ft., giving a fixed space for each automobile. One large city is considering building an underground parking space connected with the surface by an entrance and an exit ramp.

The necessity for parking places is a real and growing one, and demands the serious consideration of city planners and other officials.

The matter of cab stands (for public cabs, "taxis," etc.) is of much the same nature. In large cities these must be allowed to stand somewhere convenient to the center of pedestrian traffic. In planning a city the necessity for both parking

FIG. 57.—Auto Parking at Marshalltown, Ia.

spaces and cab stands should be considered and provision made for them.

Surface Obstructions. Every modern street is more or less obstructed by fire hydrants, lamp-posts (or light standards), poles for carrying telephone or telegraph wires, span wires for trolley lines, letter boxes, fire alarm and police signal boxes, and trees. The surface of the roadway contains covers of manholes, valve boxes, and other sub-surface structures; in the gutters and curb faces are inlets to storm sewers; and in the sidewalks are curb-cock boxes, water meter boxes (in southern cities), coal holes, vault lights, rain water cross-gutters or pipes, etc. Most of these *can* be eliminated or placed elsewhere (as on a special right of way), but the cost of doing so is not generally

warranted except where the traffic is considerable or for other reasons there is serious interference with the convenience or safety of large numbers of people.

The fire hydrants and poles referred to, the curb boxes and meter boxes, are generally placed in the parking between curb and sidewalk pavement, if there is one; or as close to the curb as possible if there is not. They are not seriously objectionable where there is a planting strip or parking, but form an obstruction on a fully paved sidewalk in a business district. A few cities have placed hydrants close to the buildings or even set into the walls with the nozzles only protruding, and this has much to recommend it.

In those cities where flush crosswalks are used and the sidewalk corner is thus not protected from vehicles by a curb, a post of some kind at the curb corner is an advantage; a fire hydrant might be placed there, but this is hardly advisable, since a blow from a heavy vehicle might break or damage it, which would be a serious matter. It is better to use at such point a short post carrying letter box or fire alarm or police signal box, or even a pole carrying wires. But only one such should be placed on a corner—more would obstruct sidewalk traffic too much. Except as just suggested, all posts and other obstructions should be kept out of the building line platform at street intersections. In business streets there would seem to be no good reason why all the boxes named should not be placed against the buildings. This would leave projecting above the surface only the poles carrying wires and lights and the trees (if any) along the curb. The trees are best there—often must be there, if anywhere.

Wires should be placed underground in conduits in all business districts; and in some cities, even small ones, are so placed on even residence thoroughfares. Trolley span wires are infinitely preferable to a line of posts in the center of the street carrying trolley wires. If the street is not too wide, they may be fastened to the buildings on either side (if fastened at a partition and anchored into it there is no danger of pulling the

front wall out of place). If poles are used, the company should be required to use steel ones rather than wood, at least on the main streets. The standard is a pole made of three steel tubes, one of which is 1 in. and another 2 in. greater in diameter than the smallest of the three, telescoped into each other 18 in. The smallest varies in diameter from 3 in. to 8 in., according to the height and pull, and is either 6 or 7 ft. long; the middle section is 7, 9 or 10 ft. long, and the bottom section is 18 to 21 ft. A "ground sleeve," a 2-ft length of steel pipe, is shrunk onto the pole 5 ft. 6 in. from the bottom. The poles are set 6 ft. into the ground. (Standard of the Am. Electric Railway Engineering Assn.) Such poles are not ornamental, but are less objectionable, safer and more permanent than wood. They generally are, and should be, set in concrete which fills the post hole in which they are set, and raked back from the roadway about 6 in. for a 24-ft. pole.

Posts for telegraph and telephone wires are generally of wood, and if so should be straight and trimmed and planed to a smooth surface. For business streets, where they are more prominent, steel poles are preferable, either pipes or built-up girder posts, or cast iron posts similar to light standards. The steel posts are smaller and therefore less of an obstruction than wood, less unsightly, and less liable to fall (wooden ones rot at the ground level and unless replaced promptly are then a menace). There is no danger from the current if proper insulators are used. (Wires carrying current at thousands of volts are almost invariably carried on steel posts for greater safety.)

Reinforced concrete poles have been used in several cities. They do not rot or rust at the ground surface, do not require to be painted, and if broken do not entirely collapse. Plain round rods are found to be as satisfactory for reinforcement as twisted or rough ones. A large number of small ones is preferable to a small number of larger ones. The number of rods may be reduced from the bottom toward the top. The poles are usually made square with beveled corners, and tapering from about 12 inches at the bottom to 6 in. at the top. Twelve reinforcing

rods for half the height, 8 continued through the next quarter-length, and 4 through the top quarter, of such size that the area of each rod is $\frac{1}{600}$ of that of the bottom of the pole, is recommended. Holes are left in the concrete for steps and cross-arm bolts. The concrete should be at least as rich as 1 : 2 : 4, the coarse aggregate passing a $\frac{3}{4}$-in. screen. The concrete is placed, rather wet, in forms laid on the side, the reinforcing rods being first set and blocked in position ($1\frac{1}{2}$ to 2 in. from the face).

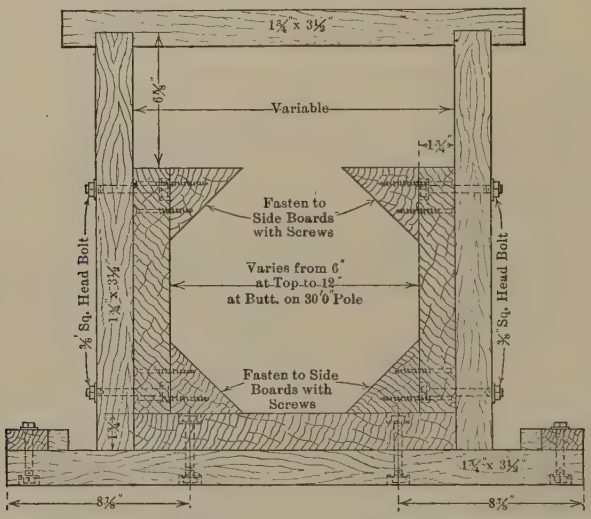


FIG. 58.—Form for Constructing Concrete Poles used at Rochester, N. Y. These frames spaced six feet apart.

The concrete is poured into the base first, and as it reaches each set of reinforcement blocking, this is removed. After three days the forms may be removed, and the pole can be handled after ten days more. One foreman and five men have averaged six 30-ft. poles a day of ten hours. The material costs about $1.50 to $2.00 per lineal foot of pole.

Methods of setting wooden poles are shown in Fig. 59. Most cities now require all companies which carry wires through the streets on poles to combine in using only one set of poles on

a street, dividing among themselves the cost of erecting and maintaining these. (The American Electric Railway Assn. has published, in its 1914 Proceedings, specifications "For the Joint Use of Wood Poles.")

Wire conduits are of course desirable, but are expensive in first cost, although this is partly or wholly offset by saving in

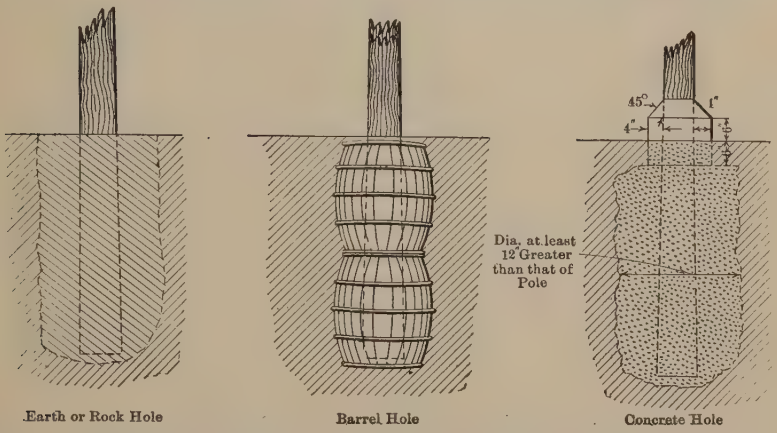


FIG. 59.—Method of Setting Poles, Recommended by The Am. Electric R'y. Ass'n.

	Depth of Hole.			
Pole Length.	In Rock or Concrete.		In Earth.	
Feet.	Ft.	In.	Ft.	In.
30′	5′	0″	6′	0′
35	5	6	6	0
40	5	6	6	6
45	6	0	6	6
50	6	6	7	0
55	6	6	7	6
60	7	0	8	0
65	7	0	8	6
70	7	0	9	0

cost of maintenance and repairs of poles and wires. Several cities, in their latest franchises, require wire-using companies to lay each year a certain length of conduit, thus gradually burying all the wires. A few cities have themselves built wire conduits and require all companies to place their wires in them, charging a rental per duct foot that covers the total annual cost.

Light standards or posts are usually made more or less ornamental. Cast iron, wrought iron or steel, and concrete are the materials most used. The first generally consist of a base, bolted to a concrete foundation or extending several feet into the ground, through which a gas pipe or wire conduit is laid; on which base a shaft is set and on this a top casting; the whole being fastened together by a rod or rods running through from base to top, by lead at the joints, or by set screws. Where a wrought iron or steel shaft is used it may or may not have ornaments attached; but the base and especially the top are generally more or less ornamented. Concrete posts are most frequently without ornament, relying for the artistic proportions and lines and the surface treatment to make them attractive. In most cases they have been used to support a single large globe on the top of the shaft. The concrete posts are generally the most substantial in appearance and are used for low-set lights; the steel shafts are the most slender, and are used for tall standards, although they may be used for all heights. The height of standards is discussed in Chapter VI.

Letter boxes, fire alarm or other boxes are generally supported on a post about $5\frac{1}{2}$ to 6 ft. high above the surface of the street. Steel, either a tube or a T or X section, is common, set in concrete. Where poles for wires already exist, the boxes can generally be attached to these and prevent the duplication of obstructions. In a number of cities these boxes are fastened to the fronts of buildings in the business districts, and in the residence districts to fences, if there are any. Boxes in such positions are less of an obstruction than along the curb. Perhaps the principal objection is that they are less conspicuous and so more difficult to find in a hurry.

Fire hydrants are generally placed near the curb; but if placed too near, the nozzles may be struck by the hubs of trucks; it is therefore advisable to keep the furthest projection at least 6 in. back of the curb face. In Boston and one or two other cities flush hydrants (set below the ground in boxes whose lids are flush with the pavement) have been tried, but have

been largely replaced with post hydrants. Hydrants would offer less obstruction if placed against or built in the walls of buildings, or the fences in front of them. An objection to this is that the steamer nozzles could not be reached from the roadway with the ordinary length of steamer suction hose; but if all were so placed, longer lengths of suction hose could be carried. Where there is such, a fire hydrant should be located in a parkway, along the edge of a park, in the center of an open square, or other place where it will offer no obstruction to traffic and will be distant from any building which, burning, might render it temporarily useless. If in a roadway, it should be protected from traffic by two or three heavy iron posts planted solidly around it. As their use for fighting fires is one of the advantages of alleys, hydrants should be placed in them or near the entrances to them. Hydrants should be kept painted a color which renders them easily located at night. A favorite combination is red with a white top.

The *tops of boxes* over curb cocks, and meter boxes and the covers of coal holes in sidewalk pavements should be set exactly flush with the surface. Too many coal hole covers are set projecting $\frac{1}{4}$ in. or more above the pavement (New York has thousands projecting 1 to 2 in.), either the entire area or crowned at the center; but this is entirely unnecessary, renders the city liable for damage suits for accidents to pedestrians, and should not be permitted. The covers should set in an iron or steel head or ring which in turn is set in the sidewalk. A groove cut in the concrete or stone is frequently used instead, the cover resting directly in this; but the edges of this groove are liable to be broken, and an iron angle bent to a ring to serve as a seat and cemented into the walk is preferable.

A slight roughness of the surface of the cover is desirable, but the projections should not exceed $\frac{1}{8}$ in. The author prefers, for roughening the cover, pyramids $\frac{1}{8}$ in. high, $\frac{1}{4}$ to $\frac{3}{8}$ in. square at the bases, the bases touching and the grooves between them being continuous. These are not slippery nor so rough as to be uncomfortable, and do not hold dirt. Even better, perhaps,

from point of view of comfort is a pan-shaped cover about $1\frac{1}{2}$ to 2 in. deep filled with concrete which comes flush with the pavement. None of these should have any provision for raising from above. They are generally about 12 to 15 in. in diameter. Concrete ones are sometimes made square.

Manholes covers or other iron surfaces which are set in the roadway should be flat—never either crowned, dished or otherwise departing from a plane. The top surface should be roughened so as to give horses a foot-hold. The depressions should be in the form of grooves rather than holes, and about $\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. deep; or if holes rather than grooves, the depressions should be not less than 3 in. across in one direction, otherwise the shoe calk cannot enter the depression to give a purchase. The author believes a checkerboard of grooves $\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. deep, separating squares $\frac{1}{2}$ in. to 1 in. on a side, furnish the best foothold. Cast iron wears down rather quickly, and the covers should be replaced when worn smooth. Efforts have been made to make a satisfactory cover filled with asphalt, but the asphalt in such covers goes to pieces rapidly. Reinforced concrete would be sufficiently rough without corrugations, but if strong enough would be too heavy to handle easily. The seat and cover should so fit that there will be no motion of the cover, as this produces noise whenever a wheel strikes it, and prevents the full strength of the cover being developed.

The strength of the cover should be sufficient to hold any ordinary wheel load. Such loads have increased recently, and two tons on a wheel is now common in cities. Allowing for impact, four tons does not seem too much to demand as the breaking load for a cover. Trucks carrying more than two tons on a wheel should avoid manholes, under penalty of having to replace any covers which they may break.

Manhole covers and other foreign surfaces in a street pavement which are constructed of material harder than the pavement should be set slightly lower than the pavement, for several reasons. It is impracticable to set the pavement and cover at exactly the same level, and the one which is lower will receive the

jar of a wheel passing over it; which jar would cause a hole to develop quickly in a pavement, thus increasing the impact of subsequent jars. The effect on the iron cover, however, will be much less serious. Again, the cover is generally supported by masonry which is practically free from settlement, while the pavement is compressible or is on a compressible cushion, or the foundation may settle (there is generally trench backfilling around a manhole, which will settle slightly), which will allow the pavement surface to settle more or less. Also, the pavement surface will in time wear down slightly (macadam even an inch or more). In a hard pavement about $\frac{1}{4}$ in. below the general surface is sufficient depression for a cover. On macadam it may be more, but probably should not be more than $\frac{1}{2}$ in. It is desirable, however, to set a ring of cobble or rubble stone around manhole heads in madacam; these being reset from time to time if necessary to keep the pavement surface uniform with that of the head. If a manhole head is not in the center of the street, it should be given the exact slope of the finished pavement.

Most sewer manhole covers and heads are round, but those for other public services are often made square. Brick, stone or wood block can be laid making a snug joint with the head more readily if it is square than if round, and asphalt can be compacted more surely close to the head. As to pavement wear, after an inspection of several thousands of both kinds in both asphalt and block pavements, the author believes that the pavement wears more rapidly (in a city) around a round than around a square head when the head protrudes above the pavement. If the rim of the head, however, is ever so little below the surrounding pavement, there is little evidence of wear with either kind. The square heads seem to be somewhat more expensive than the round, and more easily broken. (Neither are often found broken, however.) An objection to the square head is that the cover can be dropped through the opening by accident, while a round cover can not.

The flange of the head, which rests upon the masonry, should be perfectly plane, with no projections, so that it will

be free to move with any movement of the pavement, when this latter is on a concrete base or is a block pavement. With a macadam or dirt pavement, however, a flange projecting down inside the masonry, to hold the head in place, has some advantages.

A bead $\frac{1}{4}$ to $\frac{1}{2}$ in. wide and deep around the outside top rim of the head, with a square top edge, facilitates laying stone block or brick snug against the head, and also strengthens the rim against blows of wheels.

The depth from top of head to bottom flange should be sufficient to permit placing on top of the flange the regular pavement construction, foundation and all. This means about (6+1+4=) 11 in. for brick or wood block, and 3 or 4 in. more for granite block. Increased depth adds to the expense and increases the difficulty of entering the manhole; and the depth should therefore be carefully considered.

Inlets. Frames or gratings of storm water inlets and catch-basins are set in the gutter, or the face of the curb, or both, and should be set exactly flush with the curb, and flush with, or depressed very slightly below, the pavement. They should present a neat appearance and have no projections to be struck by or abrade wheels of vehicles. The top, containing the manhole, if any, is generally in the sidewalk space. When set at a curb corner, the front must of course take the curve fixed for such corner—generally a radius of between 4 and 20 ft.

Of several hundred cities reporting to *Municipal Journal* in 1915, about 40 per cent place inlets at the curb corner; 14 per cent where the property line extended intersects the curb, 7 per cent back of this line, and the remainder between this line and the corner.

The inlet openings, when in the curb, are generally from 4 to 10 in. high and 15 to 60 in. long; 6 by 30 being perhaps the average. The area of opening should vary with the amount of water to be received, but is better too large than too small. The opening is generally provided with some kind of guard or grating (preferably wrought iron bars, either horizontal or ver-

tical, or both) to prevent sticks and other large articles and children and animals from falling or being washed into the sewer. There should be no more of these than is necessary to accomplish this purpose, as too small areas of openings are apt to cause the inlet to be stopped up. One horizontal bar if the opening is more than 6 inches high, and a vertical one for each 10 in. if the opening exceeds 15 in. in length, is recommended. The opening may be formed by omitting the curb for the desired length of opening and placing over the opening a stone, concrete or cast iron cover which extends into the sidewalk so as to cover the basin and contain the manhole opening; or by using an entire cast iron construction which acts as a head to the inlet basin, several styles of which are on the market. Where the sidewalk pavement extends to the curb at the inlet, it is preferable to make the top of concrete or stone, whichever is used for the sidewalk. Where there is parking adjacent to the inlet, the cast iron is perhaps preferable.

Gutter inlets are generally 15 to 18 in. wide and 20 to 36 in. long, of cast iron, with slots $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. wide. The slots are made either parallel to or at right angles to the curb; the latter seems preferable, as narrow wheels may catch in the former. Quite a number of cities use the D or "half moon" grating, a semi-circle with a diameter of 18 to 36 in., the straight side against the curb. A wrought iron frame containing wrought iron rods or flat bars set vertical, is sometimes used for large openings.

At *cab-stands*, markets, or at any other places where horses stand frequently and for a considerable time, special paving should be placed; for this purpose a good brick, stone block or concrete may be used. As a great deal of foul water is likely to be found here, the pavement should be smooth (to permit it to run away readily) and impervious. Smooth granite ("modern specification") with impervious joints is the most durable and can be kept clean by daily flushing with the hose. A sewer inlet should be placed at such a point; if at a market, protected by a grating with small openings to keep out vegetable refuse matter.

Watering troughs for horses and dogs, and drinking fountains or faucets for human beings should be provided wherever large numbers of teams and persons congregate. Troughs or fountains for horses should also be located at the outskirts of

Fig. 60.—Substantial and Artistic Granite Fountain, Harrisburg, Pa.

the city on streets used by any considerable numbers of farmers in reaching the market or business center. In the slums or other congested districts, drinking fountains should be numerous. It is desirable that watering troughs be placed where they are available to as many users at once as possible—in a salient rather than a reëntrant angle, but preferably in the open,

approachable from all sides. The foundation should be deep and solid, that the water supply pipe be not broken or sprung by a settlement of the structure, and that settlement be not caused by the water which is sure to be spilled upon the ground. There must ordinarily be a drain leading the overflow or waste to the sewer or gutter; although a horse trough may be provided with an enclosed ball cock for shutting off the supply when the trough is full. The latter also prevents waste of water, which may be enormous, amounting to 1,900,000 gals. per year in one horse trough in Port Chester, N. Y., which supplied an average of 300 horses per day. Around horse troughs the surface should be covered with an impervious and durable pavement; stone block or brick on concrete, on the roadway; concrete or asphalt on the sidewalk. The trough should hold at least 18 in. depth of water and be 2 ft. in the clear in its least dimension; and the water surface, which should be not more than 4 to 6 in. below the edge of the trough, should be not less than $2\frac{1}{2}$ nor more than $4\frac{1}{2}$ ft. from the surface of the ground $3\frac{1}{2}$ ft. being a good height. A trough may be of masonry, cast or wrought iron, bronze or other metal, or of wood. The last is the cheapest; cast iron probably the most common in cities, and obtainable from makers of ornamental cast iron. A cheap cast-iron trough can be made of a 40 in. to 50 in. cast-iron pipe 4 to 6 ft. long, set upright with the bell on top, closed at the bottom by being set down a foot or two into a concrete foundation which is afterwards washed over, inside the pipe, with Portland cement grout; an inlet and outlet pipe being tapped through the pipe shell in or just above the concrete.

When in prominent places, and especially in parks, watering troughs are much in evidence and care should be taken to have them artistic—which does *not* mean ornate. A bowl cut from a large stone or cast of concrete, or of bronze, is preferable to iron. They must be heavy enough and so solidly set that wagon poles will not break them or move them bodily.

Drinking fountains may be small bowls into which a spring faucet discharges; but present practice is to install only some

form of fountain to be used without a cup, the water discharging vertically and flowing over a mouth-piece, which it thus washes. Even when these are used, there is apt to be some splashing of water onto the ground, and they should be surrounded with a strip, at least, of pavement draining to gutter or sewer.

In several instances the water is cooled in summer by ice. Fitchburg, Mass., installed 8 fountains, each having a brick ice box with suitable piping upon which the ice was placed, each box holding about 2000 pounds of ice, in which box the water was cooled on its way to the fountain faucet. In Boston an ice box $4 \times 3 \times 4$ ft. contains 315 ft. of $\frac{3}{4}$-in. pipe, both vertical and horizontal, around its sides and bottom, and reservoirs of two $2\frac{1}{2}$ ft. sections of 8-in. cast iron pipe; in which box shaved or chipped ice is packed around the pipes and reservoirs, through which the water for the fountain passes. The faucets of drinking fountains should be about 3 ft. above the ground—not too high to permit their use by children—and should be self-closing.

Awnings, while in no sense a matter of engineering, are sometimes under the jurisdiction of the city engineering department as "street obstructions." No part of an awning or its frame should be allowed to come within $7\frac{1}{2}$ ft. of the sidewalk, to clear umbrellas. It is best to require awnings to be supported entirely from the buildings; but if permanent ones are supported on posts, the posts should be at the curb, strong enough to be safe, but as slender as possible to offer the minimum obstruction. Owners should be required to keep them in repair, painted, etc., so they will disfigure the street as little as possible.

Street trees, street signs, street lights, public markets and comfort stations will be found discussed in Chapters VI, IX and X.

Art. 13. Street Railways

While there are few American cities which own or operate street railways, they occupy the public streets and their effect upon the pavement and upon the use of the roadway is very great; moreover they are nominally under some control by the city, part of which is exercised by or through the city engineer

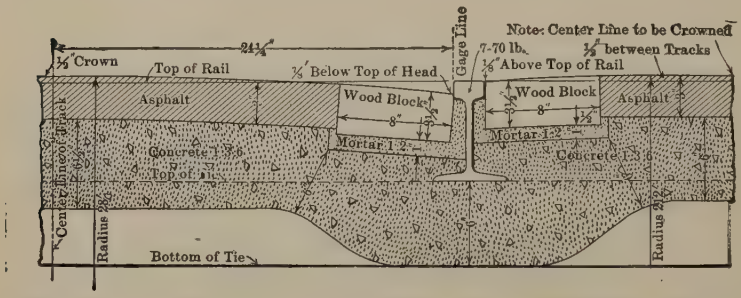
and often forms one of his most vexing problems. The most important of these as regards construction is how to prevent deterioration of the pavement along the track, and to secure such construction of track as will least interfere with traffic.

Pavement deterioration along rails is due partly to the causes which produce wear at any continuous longitudinal joint in a street, partly to the difference in hardness and resiliency of steel and paving material, and largely to the vibration of the track under passing cars; and it seems impracticable to maintain a pavement in good condition unless such vibration is reduced to a minimum. Where the ties (to which the rails are spiked) themselves move appreciably, there is liable to be a break in the pavement above the ends of the ties, and the raising of a ridge in the pavement above each tie. The problem therefore divides itself into two parts; the securing of sufficiently rigid track construction; and, given this, securing a pavement which will suffer minimum wear along the rails.

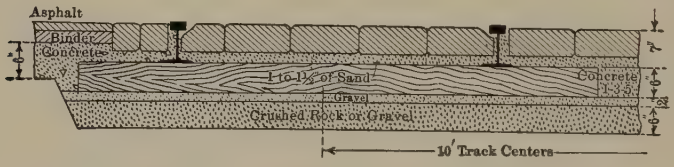
Track Construction. The standard method is to spike the rails to wooden ties, and to bed the ties on a foundation of either concrete, or a ballast of crushed stone, gravel or cinders (preference being in the order named). Where the street pavement is on a concrete base, this base should be continued under the track space with a depth of at least 6 in., the top of the concrete base here being from 7 to 12 in. lower than that of the pavement base generally, the depth depending upon the remaining track construction. Where the street pavement is not upon a concrete base, concrete may still be used under the track, and is desirable if the ground does not furnish solid support throughout; but 6 or 8 in. of ballast, thoroughly rolled as in making a macadam pavement, is the more common construction, is cheaper and may be admitted as satisfactory.

On this base the ties are laid, the standard size of tie being 6 in. × 8 in. × 8 ft. Where the base is of concrete, 3 in. of crushed stone, gravel or sand is sometimes spread and the ties firmly bedded in this. With either concrete or ballast base, when the rails have been laid and spiked in place with tie plates under

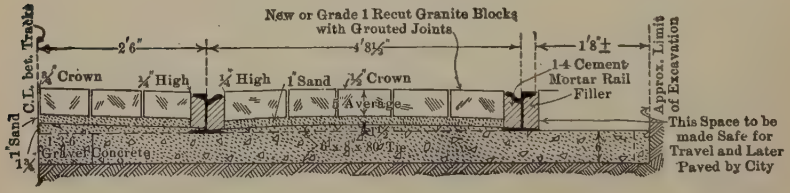
them, and brought exactly to alignment and grade, and the ballast under the ties been thoroughly consolidated by tamping, the entire space between the ties and for about 6 in. beyond the ends of the ties is filled with concrete, which is brought up to the level of the pavement foundation, which will ordinarily be approx-



Asphalt and Wood Block Construction, New Britain, Conn. Concrete Beam Construction.



Standard Construction, Minneapolis, Min. Plain Ballast Construction.

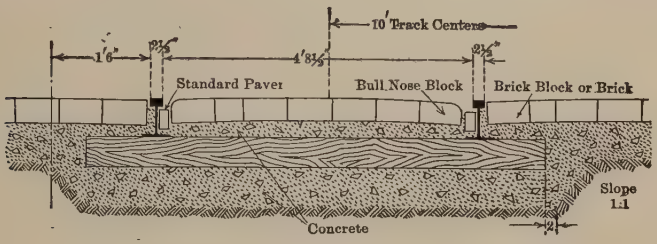

New or Grade 1 Recut Granite Blocks with Grouted Joints
1-4 Cement Mortar Rail
Filler
Approx. Limit of Excavation
This Space to be made Safe for Travel and Later Paved by City
Concrete

Standard Construction, Brooklyn.

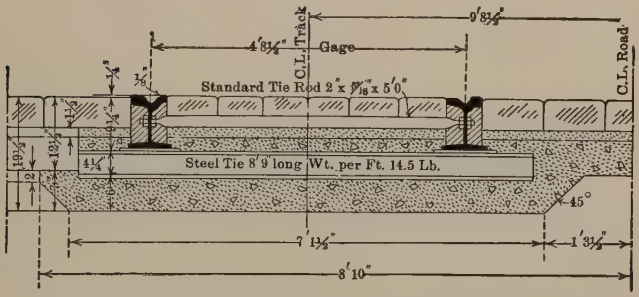
FIG. 61.—Typical Methods of Track Construction.

imately 2 in. above the tops of the ties. The method employing concrete in the bottom is called the "concrete slab sub-ballast" construction; the other is known as the plain ballast construction. These two as described above are the forms recommended in 1915 by the American Electric Railway Engineering Association, and are shown in the accompanying illustrations. Most

of the large cities which use the concrete slab foundation omit the sub-ballast and fill the entire space under, around and above the ties with concrete. A few of them, instead of using the wooden ties use steel ties 6 ft. 4 in. or 6 ft. 6 in. long, these being in the form of I-beams, to the top of which the rail base is bolted. The use of the ballast advocated by the railways between tie and concrete is to reduce the rigidity of the track, which is claimed to



Standard Construction, Seattle. Concrete Slab Sub-ballast.



Steel Tie Construction. Chicago.

FIG. 62.—Typical Methods of Track Construction.

cause corrugation of the rails; also it is claimed that the ballast reduces the noise.

In this, as in any construction which uses wooden ties, the rails should be fastened to the ties with screw spikes. Where concrete is brought up to the under side of the rail throughout its length, the ties serve little purpose except to hold the rails to line and grade until the concrete has been placed and set; consequently spacing about 10 ft. apart appears to be sufficient.

Another method, known as "concrete beam" construction, consists in excavating under each rail a trench 10 or 12 in. deep below the bottom of the rail and about 18 in. wide, and filling the trench solidly with concrete in which the rails are bedded. The rails are fastened to the concrete by anchor bolts spaced 12 in. to 24 in. apart along each edge of the base of the rail, these being driven into the green concrete. Ordinarily the space between these concrete beams in each track is filled with a concrete slab or spacing strut 4 to 6 in. deep. Beam construction distributes the load over a smaller area of soil than the slab, and is desirable only where the ground is unusually firm.

The cheapest construction possible is to use no concrete, but to bed the ties on the natural soil; but this should never be permitted in city streets, as water is sure to collect under the ties and the motion of the ties gradually works a depression under each one, allowing the track to settle as cars pass over it. The cheapest construction permissible for a city street is that using stone ballast throughout, a ballast base 6 in. thick being spread and rolled thoroughly to receive the ties. After the ties (spaced about $2\frac{1}{2}$ ft. centers) have been set and track brought to permanent position by tamping ballast under the ties, additional ballast is placed between the ties to the level of their tops and thoroughly tamped in place. On this may then be laid whatever pavement is decided upon. If the pavement between the tracks, however, is to be laid on a concrete base, this concrete should be carried down to the bottom of the ties throughout. In construction like the above, where the ties are relied upon to support the rails, it is desirable to use thoroughly creosoted ties. Uncreosoted oak ties have a life ordinarily of four to eight years, after which the pavement between and along the rails must be removed in order to renew the ties, which seriously obstructs traffic.

In any construction in which concrete is used, cars should be kept off of the rails for at least a week or ten days to allow the concrete to set. If this is not done, both ties and rails will be forced down into the concrete by each passing car and, spring-

ing back to place afterward, leave open channels in the concrete in which the track can vibrate; which vibration will gradually pulverize the concrete under the rails, thus increasing the motion of the track as time passes. If it is a case of reconstructing the track, and traffic must be continued meantime, the new construction, if it is a double track, can be built one section about a block long at a time, temporary switches being set at each end to throw the traffic on to the other track temporarily. If it is a single track, a temporary track on wooden ties can be laid on the roadway alongside that under construction, to which cars are diverted by switches from the track already completed at one end and onto that not yet removed at the other.

Rail Sections. Having the solid base, the next question is the rails. Numerous sections of rail have been and are used, but the principal difference of opinion at present is as to the relative advantages of the T rail and the grooved girder. A majority of street railway companies insist that only the T rail is satisfactory, and several city engineers also favor this section. On the other hand, the majority of city engineers and street officials, and especially those in the largest cities, insist that the T rail should never be laid in a city street.

In any construction, a groove must be left alongside the rail head to receive the flanges of the wheels. In the grooved rail, this flange groove is constructed in the steel itself; while if the T rail is used, the groove must be built in the pavement, and as ordinarily constructed is the full depth of the T rail head, or $1\frac{1}{2}$ to 2 in. Teams traveling with one wheel in the groove, in turning into and out of this wear the pavement along its edge and so widen the groove until it becomes more or less of a menace and detriment to traffic. The grooved rail, on the other hand, furnishes a narrow groove in a steel surface, both sides of the groove having the same elevation, and therefore the pavement can be made continuous in surface except for this shallow and comparatively narrow groove.

The companies' arguments are that the mills can make the T rail head more durable against abrasion of car wheels than the

grooved rail head can be made; that the smaller surface of steel exposed to the sun results in less motion due to temperature changes; the rails are cheaper in first cost, and when the side of the head next to the flange groove is worn, the rail can be reversed and thus its life almost doubled. They also claim that sharp edges are worn on the side of the steel groove by steel-tired wheels, which edges cut and strip the rubber from narrow rubber-tired wheels.

If T rails are used, these may be 4 to 5 in. high on unimproved streets; but on streets where the pavement is placed on a concrete base, whether T or grooved rail be used the rail should be at least 7 in. high, in order that the concrete base may be continued under the pavement on top of the ties. Eight-in. or 9-in. girder rails also are used and would seem to be necessary where granite block pavement is employed. The girder rails, or those more than 4 or 5 in. high, generally require to be tied together by tie rods at intervals to prevent their spreading out of exact gauge.

The life of a rail is ordinarily from five to fifteen years; or is placed by different engineers as the passage of from 2,500,000 to 6,000,000 cars over it, probably depending upon the weight of the cars and the solidity of the roadbed. The wear on grades is greater than on the level. The wear is in some cases greater on the up track of a grade, in others on the down. Measurements made at Sheffield, England, on a 108 lb. grooved girder rail gave the following results:

Gradient	No. of Months in use	No. of trips	Reduction of Depth of Groove		Relative Reduction per Trip	
			Up	Down	Up	Down
1 : 15	34	764,200	0.09	0.25	1.05	2.90
1 : 15	34	166,734	0.03	0.07	0.08	0.18
1 : 17	30	65,384	0.025	0.06	0.025	0.06
1 : 23	34	865,507	0.09	0.15	1.19	1.98
1 : 79	26	172,558	0.028	0.06	0.07	0.16
1 : 84	30	65,384	0.06	0.06	0.06	0.06
1 : 268	19	254,412	0.035	0.07	0.13	0.27
1 : 787	34	593,704	0.06	0.125	0.54	1.13

The wear on the down track is here seen to be twice that on the up. On the other hand Tillson refers (" Street Pavements," page 450) to " the increased wear that is always noticeable on an up-grade track over the track used by down-grade cars, especially where the cars are moved by the friction on the rails."

Paving Along Tracks. In selecting the pavement to be placed between and along rails, consideration should be had of the vehicular and car traffic, both present and estimated for the future; the grade and crown of the street; the class of property adjacent; the type of rail; and the relation of cost of the several pavements available to the service to be rendered. Stone block is considered by some engineers the only pavement to lay between and along rails on thoroughfares, and most agree that either this or brick or wood block is decidedly preferable to sheet asphalt or any other sheet pavement. A few cities have succeeded in laying sheet asphalt, and even the better grades of bituminous concrete, in immediate contact with the rails and maintaining the pavement in good condition without ruts or holes along the rail. There are few such instances, however. Members of the American Electric Railway Engineering Association in 1915 stated their preferences in the following order: Granite block; Medina sandstone block; creosoted wood block; vitrified brick; asphalt block; sheet asphalt; bituminous concrete and bituminous macadam; and finally waterbound macadam.

Granite block, if used only for a strip along the rails where there is a sheet paving outside the track, should be laid as stretchers (three or more rows of them), or as headers without toothing. For cushions under granite pavement, dry grout (sand and cement mixed and used dry) is probably better than a plain sand cushion.

Brick seems to be laid more generally in the track space than any other material, because of its relative cheapness, the ease with which it is laid, and its adaptability to laying without waste in track space.

Scoria block has been used by only four or five cities, which found it non-uniform in texture and extremely brittle.

Sheet asphalt adjacent to rails is considered very unsatisfactory, requiring constant maintenance to keep it in good condition. One city has found the cost of maintenance of asphalt along tracks to amount to 55 cents per square yard per year, while granite maintenance was but 27 cents. In Buffalo repairing asphalt pavements has cost 33 per cent more on streets with, than on those without, tracks. In laying asphalt pavement directly against rails, especial care should be taken to compress the hot asphalt material thoroughly under and around the head and flange of the rail. In cold weather this can not be, done properly without first warming the rail, as otherwise the asphalt will be chilled when it comes in contact with the cold rail and cannot be properly compressed. The surface of the asphalt should be laid even with the top of the rail; if it is laid lower, the latter not only forms an obstruction to travel, but vehicle wheels will follow along the projecting rail, and gradually wear a rut there; if it is laid higher than the top of the rail, the wheels of vehicles, and particularly the tread of broad car wheels, will abrade the edge of the pavement.

Bituminous macadam is suitable only on the outskirts of cities, or on other streets where vehicular traffic is light; moreover it costs more in the long run than brick pavement, and is difficult to replace.

Waterbound macadam, if properly made, may be used by small municipalities or in outlying districts, but substantial repairs are not easily made. This material should be used only as a temporary filling, to be replaced in the future by more "permanent" pavements.

Concrete pavements have been used next to car tracks for so short a time that definite conclusions are difficult, but some cities report it undesirable on account of the "impracticability and expense of maintenance, its tendency to expand and break up, and the rapidity of wear."

Whatever the type of pavement or of rail, the pavement should be laid $\frac{1}{8}$ to $\frac{1}{4}$ of an inch higher than the rail, if on a con-

crete foundation, and the difference should be greater than this where there is no concrete pavement foundation, to allow for future settlements. Exception to this is sometimes made in the case of T rails, where, instead of a groove being made, the pavement next to the inside of the rail is sloped to a maximum depression of $\frac{3}{4}$ to 1 in. below the top of the rail, the slope beginning about 12 in. back from the rail. This plan causes a bad drop to the pavement from the rail head and is particularly undesirable. If a T rail is used, it is preferable to provide the flange space either by using nose block or by stopping the pavement an inch or an inch and a half away from the head of the rail, the space between this and the rail being filled by concrete, by a paving block laid as a header just under the head of the rail, or other construction. Under the latter form of construction some cities fill the flange space so formed with asphalt pavement filler or sheet asphalt mixture, in which the flanges of the wheels form a flange space in one or two trips. With a grooved rail, in which the groove is provided by the rail itself, no such special construction is required, but the pavement is laid close up to each side of the rail.

The space between the pavement and the rail under the head of the latter—the flange space—should be filled solidly with concrete or mortar at the time the pavement is laid. One common cause of the rapid deterioration of block pavements along rails, where the blocks are laid upon a sand cushion, is that the flange space is not thoroughly filled and the motion of the rail jars and works the sand from under the blocks into the interstices in the flange space, thus allowing the blocks to drop. For this reason, among others, engineers are abandoning the use of sand cushion under pavements on railway track streets, setting the brick, wood or stone block directly upon the concrete, or upon a mortar bed spread on the concrete. If this is not done, it is certainly advisable, when laying the pavement, not only to fill the flange space with mortar, but to spread the mortar on the foundation for at least 6 in. from the rail, and bed the blocks in this.

If the street is paved with macadam, the rails should be at least 6 or 7 in. deep to secure a sufficient thickness of road metal above the tie to bond solidly with the rest of the pavement. The use of tie rods between rails is especially necessary here, because the pavement cannot be relied upon to hold the rails in line, and the spikes may pull out of the ties, especially if the latter begin to rot.

If macadam is used along the rails, probably the only plan for preserving the pavement in satisfactory condition is continuous care to patch all holes or ruts along the rail as soon as they appear. It is desirable to pave with brick or some other material between the rails and for 16 or 18 in. outside of them. It will be easier to keep macadam in good condition along the joint which it makes with the brick pavement strip than where the macadam is against the rail, because the outer bricks do not vibrate under traffic as does the rail. In connection with neither macadam, sheet asphalt, nor other sheet pavement is it advisable to tooth the blocks into the other material. This has been done in a number of cases in the past with the idea of avoiding the continuous longitudinal joint. Such a joint is objectionable, since ruts are almost sure to form along it; but toothing has been found to be even more objectionable, because it is impracticable to properly consolidate macadam, asphalt or other sheet pavement in the recesses of the toothing, and the pavement in such recesses quickly goes to pieces, leaving the joint between the materials very ragged and rough for traffic.

For ordinary dirt roads it does not seem worth while to go to great expense in the railway construction, since nothing apparently can be done to keep the road in even tolerable condition if there is much travel on it. Here a $4\frac{1}{2}$-in. T-rail may be used on wooden ties resting directly on the soil. As holes and ruts form along the rail, these may be filled with broken stone thoroughly rammed or rolled. Probably a better plan, where it is not too expensive, would be to lay a strip of cobble stones 12 to 24 in. wide along each side of each rail.

Location of Tracks. A single track may be laid either in the center of a street or near one side. Where there is a double track, both tracks may be laid in the center, both on one side, or one on each side of the roadway.

Where a track is near the curb, either vehicles must be prevented from standing drawn up to the curb, or the cars will be delayed more or less by vehicles so standing. Also, on a straight track the two rails should be at the same elevation, but if the roadway is given its ordinary crowning section, the rail nearer the curb would be lower than the other. However, the track may be made level and a depression serving as a gutter be left just outside the outer rail and this and also the track space be drained to catch basins placed at low points in the track. The interference of cars and standing vehicles is the serious objection to such location; and the track or tracks are ordinarily placed in the center of the street.

With certain widths of street this might give a width between track and curb at each side which would be unnecessarily wide for one vehicle but not wide enough for two. In such cases the track has sometimes been located nearer one curb than the other, leaving ample room for two teams to pass between track and curb on one side and still room for one team to stand at the curb on the other side. The conflict between slope of pavement and uniform elevation of rails is an objection to this location.

In turning a corner it is necessary to lay the track with a radius of at least 50 ft. and more is probably necessary for large suburban cars. As the radius of the curb corner is ordinarily between 5 and 20 ft., it is evident that, unless the track center is 30 to 45 ft. away from the curb, the track must approach near the curb as it swings around the corner. If possible the distance between track and curb at the corner should not be less than 10 or 11 ft., as this just gives room for a vehicle to pass between curb and car. If necessary, the radius of the curb could be made longer to secure this.

The outer rail on the curve should be higher than the inner

rail, and if the track approaches nearer the curb at the corner, this will be secured by conforming to the regular roadway cross-section, since the track will then be on the slope of the pavement rather than on the crown. In some cases, however, side-hill street construction may have required that the roadway slope continuously down from the curb rather than rising to a crown; which condition, if both rails were laid in the surface, would make the outer rail lower than the inner. This difficulty may sometimes be met by a regrading of the intersection, such as putting an unusually deep curb at the corner, with steps at the crossings, thus permitting the roadway to slope down toward the curb without changing the remainder of the roadway cross-section. Another plan, which was used at Winston, N. C., was to make a two-level street at the corner, the two levels converging 100 ft. or so each way beyond the corner; the track being placed on the upper level, the pavement of which was given a pitch toward the upper gutter; while the lower roadway, which sloped toward the lower gutter, was separated from the upper by a concrete retaining wall having a maximum height of about 3 ft.

Careful consideration should be given to the matter of turnouts in single-track roads. The company will usually indicate where it desires these, but should not be allowed to place them where they will be unduly dangerous or inconvenient to traffic. They should not be placed at a street junction or intersection; at a point in the roadway which is unusually narrow; opposite fire engine houses; on or at the foot of a grade where there would be the greatest tendency to erosion (this applies especially to dirt or macadam streets). The diamond turnout is usually to be preferred, although in some cases it may be preferable to throw all of the turnout on to one side of the street, leaving the other side of the track unobstructed for the full width.

Car barns should be placed off of the main thoroughfare turnor if on a thoroughfare, not more than three or four tracks or itself; outs should be allowed entering the car barns, the company being required to provide all additional switches and sidings necessary on their own property. Generally it will be possible to place

the car barn in the outskirts of the city and facing either on a secondary thoroughfare or on a private way run in from the main thoroughfare. The object is to avoid as far as possible the interference with vehicular and sidewalk travel caused by the numerous sidings extending from the main tracks into the car barns.

CHAPTER IV

BRIDGES AND WATERWAYS

Art. 14. Bridges and Viaducts

A CITY BRIDGE or viaduct is a continuation of a street or road across a stream or valley, and should be so treated. It should be designed with width of roadway and of sidewalk sufficient to carry the traffic, just as a street is designed. In fixing the width, however, no allowance need be made for standing vehicles. Where it forms part of a main traffic street, the lines of roadway and of sidewalks should be continuous with those of the street, and the grade also if possible. Where the traffic is not expected to require the full width of the street for some years, however, the bridge may be made narrower, since a wider one can be substituted for it more easily than a street can be widened. In general, no roadway should be less than 20 ft. wide between trusses, or 18 ft. between wheel guards. The width between steel trusses should not be less than one-eighteenth of the span.

Where there is a street railway, the clear distance between the center line of either car track and the nearest truss should not be less than 7 ft., and that between one of the trusses and the center of the nearest track should be at least 12 ft. to allow room for a vehicle. If possible there should be 12 ft. on both sides. The clear head room above the bridge floor, for a width of 6 ft. on each side of the center line of the roadway, should be at least 15 ft.

Instead of a bridge with the girders or trusses above the floor, a deck bridge, in which the floor rests upon the tops of the girders or trusses, or an arch bridge, is preferable in that the members of the bridge do not offer obstructions to traffic, the total width of the bridge is available for use, the danger of

collision of vehicles with truss members is removed, and there is greater freedom in dividing the width into sidewalk, roadway, railway tracks, etc. The appearance of the deck bridge and the freedom of view from it are great arguments in its favor. However, an arch, either steel or masonry, or a truss, when under the floor, reduces the head room under the bridge for either railroad or road traffic or for stream floods, which may make the deck form impracticable.

Concrete (generally reinforced) whether it be in the form of an arch or a girder bridge, gives a more pleasing effect as a city bridge than any steel structure. The arch form is objectionable where the bridge is over a street, because of the reduced head room over the sidewalks; for these must pass close to the abutments unless the span be made excessive; and unless the arch be very flat or the head room at the center very high, the springing line must be at or near the ground level. Where there is abundant head room and the springing line can be placed 6 or 7 ft. above the sidewalk level, the arch is a desirable construction; but where, as is generally the case in cities, the head room must be kept down to the least possible, the girder is preferable, even if narrow piers be placed at the curb lines to give shorter spans.

A bridge is a very prominent structure, visible for long distances, and thought, advice and money should be employed to secure a pleasing appearance, artistic and appropriate to the surroundings. This should apply to its appearance as viewed from the side; from the end, looking across it; or while standing upon it.

The clear head room over a street is usually required to be 13 to 16 ft. as a minimum, the latter where trolley cars are to pass under. Over a railroad, 18 to 20 ft. over each track is generally required, although 15 ft. may be sufficient for a siding. If the bridge is over a stream, the bottom of the truss or girder should be sufficiently high to clear the greatest floods. In the case of a navigable stream, the Federal Government must be applied to for permission to bridge, and will specify

the minimum head room required, unless a movable span is provided.

The width between abutments, if the bridge is over a stream, should be ample to prevent a damming back of floods. (This sounds like an unnecessary suggestion, but a very large percentage of existing bridges were not so designed.) To insure this, all available data should be used and a thorough study made of the stream flow and of probable maximum run-off of the watershed in determining the area of waterway required.

It is recommended that the type of bridge employed be selected as follows:

For spans up to 30 feet—rolled beams.

For spans from 30 to 40 ft.—plate girders or rolled beams.

For spans from 40 to 80 ft.—riveted low trusses or plate girders.

For spans from 80 to 200 ft.—riveted high trusses.

For spans over 200 ft.—pin-connected high trusses.

The depth of a rolled beam should be at least one-twentieth its span; that of a plate girder at least one-twelfth, and that of a truss at least one-tenth.

Loads. In computing dead loads, the unit weights of materials may be taken as follows, in pounds per cubic foot: steel, 490; concrete, 150; brick, 150; macadam, 130; asphalt, 135; sand or earth, 100; stone, 160; creosoted timber, 5 lb. per foot b. m.; untreated oak timber, $4\frac{1}{2}$ lb. per foot b. m.; untreated pine, 4 lb. per foot b. m.

For live loads, the following are recommended:

For the floor and its supports, and for trusses of spans less than 50 ft. on each car track a concentrated load of 24 tons evenly divided between two axles, spaced 10 feet center to center with wheels spaced 5 feet center to center on axles, should be assumed to occupy a width of 6 feet on each side of the center line; on the remaining floor surface, exclusive of sidewalks, a uniform load of 125 pounds per square foot, and on sidewalks a uniform load of 100 pounds per square foot.

For trusses of spans between 50 and 100 feet in length, a uniform load of 1800 pounds per lineal foot for each car track (assumed to occupy a width

of 10 feet) and 100 pounds per square foot of remaining floor surface, including sidewalks.

For trusses of spans greater than 100 feet, the live load on each car track may be reduced by 5 pounds, and that on each square foot of remaining floor surface by 0.2 pounds, for each foot of span in excess of 100 feet; provided that in no case should these loads be reduced below 1200 pounds and 80 pounds respectively.

In considering concentrated loads, each wheel load should be assumed to be distributed over an area of floor surface 5 feet square.

The top lateral bracing in deck bridges and the bottom lateral bracing in through bridges should be designed to resist a lateral wind load of 300 pounds per linear foot, one-half of this to be treated as a moving load. The bottom lateral bracing in deck bridges and the top lateral bracing in through bridges should be designed to resist a lateral wind load of 150 pounds per linear foot.

Provision should be made for a longitudinal force exerted along either track of any street railway crossing the bridge, equal to 20 per cent of the weight of the heaviest electric car or train which can reasonably be expected to come upon the bridge.

To the maximum live-load stress in each member should be added an impact equal to $\frac{100S}{L+300}$, in which S is the computed live-load stress in the member and L is the loaded length of bridge (in feet) which produces the maximum live-load stress in said member.

If there is a curved track on the bridge, allowance should be made for the centrifugal force produced by two heaviest cars coupled together and moving at 50 miles an hour.

The above is for bridges carrying street cars and ordinary street traffic. For bridges in parks or cemeteries, or others which will not need to carry street cars or heavy road rollers or tractions engines, 15 tons concentrated load may be substituted for 24 tons.

The floor system, in all-steel bridges should be rigidly attached to the main girders, to reduce noise and make a stronger bridge. The floor should be so constructed in all ways as to deaden the noise of traffic over it, for which reason there should be no loose floor planks or any other movable parts. Asphalt and wood blocks are excellent materials for paving bridge floors, giving lighter pavements than most others. Planks are not so dur-

able, but are commonly used on steel bridges of minor importance. The surface planks should be laid crossways of the street, and, if but one thickness be used, these should be at least 3 in. thick if of pine, or $2\frac{1}{2}$ in. if of oak, and not less than $\frac{1}{12}$ of the distance between joists or stringers. A better plan is to lay on the stringers a diagonal course not less than $2\frac{1}{2}$ in. thick, and spaced $\frac{1}{2}$ in. apart; and on this a transverse course $1\frac{1}{2}$ in. thick. If the former are creosoted they will last much longer, and only the thinner planks will then neeed to be replaced when the surface becomes worn. All planks should be laid with the heart side down. Philadelphia lays surface plank diagonally, finding that this prolongs the life, the edges wear more uniformly, and vehicles ride more smoothly.

Steel floors can be made of buckle plates or corrugated sections covered with concrete for a pavement foundation; or the floor can be made of slabs of reinforced concrete; on either of which can be placed any kind of pavement. The steel plates should be at least $\frac{5}{16}$ in. thick, and thoroughly painted on both sides. The concrete used on such plates should be at least 2 in. thick at the thinnest section. Allowance must be made in designing the bridge for the additional weight caused by concrete floors and stone block or other heavy paving material which may be used.

There should be a curb between the road and sidewalk at least 10 in. high, and some insist on 16 in. The sidewalk may be raised this distance above the roadway, or the two may be on a level and a wooden curb or wheel guard bolted to the floor between them; or a concrete curb built in connection with a concrete pavement foundation. The curb here is to protect pedestrians from vehicles and horses rather than from surface water. If wooden wheel guards are used, the timbers should be spliced with 6-in. lap joints and bolted to the joists at intervals of about 5 ft.

Provision should be made for draining all parts of the floor, both roadway and sidewalk, in such a way that the water will go clear of all metal work.

The railing should be at least 3 ft. 6 in. high. It should have no opening in it wider than 6 in. It should be so fastened and braced as to withstand a lateral pressure of 50 lb. per lineal foot. Where there is no sidewalk between the roadway and the railing, the latter should be much more substantial, and a heavy wheel guard be placed inside of it.

Provision should be made for change of length of bridge, due to temperature, of at least $\frac{1}{8}$ in. for each 10 ft. of span, by expansion joints in the floor over piers and abutments, and by an expansion bearing at one end of each span. For beam and girder bridges sliding joints may be used, but for truss bridges, rollers or rockers should be used.

The drainage of bridges and viaducts is as important as that of streets. A single span will generally drain to the street at each end; but a viaduct must in most cases be provided with several outlets from the gutters. These will generally be placed at piers (in some cases the pipes being imbedded in the masonry to conceal them, for appearance's sake) and the water led to a gutter or sewer at the base of the pier.

A street passing under a bridge, especially a low and wide one, should be well lighted at night, that it may not afford concealment to any wrongdoers. A street which passes over a bridge, especially a bridge of several spans or a viaduct, should be generously lighted. There being no houses to reflect the light, probably double the candle power of total lights is required to secure a given illumination of roadway as is required on streets.

Painting. After erection, all metal work should be thoroughly cleaned and given two coats of paint, all recesses which might retain water being filled with thick paint or some waterproof material. Philadelphia found sand-blast cleaning to cost slightly more than hand cleaning, but to remove scale and rust much more completely in less time. The same city obtained favorable results by applying the priming coat of paint with an "air brush."

Repainting of steel bridges should not be neglected, and

never deferred until the steel is exposed. If it should become exposed in places, and wherever the paint may have blistered, the surface should be cleaned of all rust until bright and then given a first coat; and after this has dried, it and all other parts should receive a second coat. The cleaning may be done by wire brushes or by sand blast. Repainting is expensive, say $25 for a 100-ft. span, and increasing nearly as the square of the length, and this is one of the advantages of a concrete or stone arch bridge.

Maintenance. *Inspection* of all steel bridges should be made once a year or oftener. To do this thoroughly: 1. Look over the pins and see that they are not bent and fit perfectly. 2. See that all connecting members fit perfectly, without any play. 3. See that all rivets, especially at connections and intersections, are tight and not corroded. 4. Examine turnbuckle connections on counter-rods, see that they are tight and the threads are not stripped. 5. Inspect the painting thoroughly. 6. Examine all metal parts for defects or rust. 7. Inspect floor hangers, beams and floor surface. 8. Examine masonry of sub-structure, especially for the first year or two after being built, for settling and cracking, or displacement forward.

Corrosion of steel bridges over railroads by sulphur in the smoke from the engines may become very serious. It has been prevented by fastening a wooden ceiling under the entire bridge. In St. Louis 2-in. planed, tongued and grooved sheathing was used, offering no lodging place for sparks, the corners protected by galvanized iron flashing. The total loss of head room was less than 3 in. Another method, more expensive but more permanent, is to encase the entire bridge—girders and floor beams and other metal parts—in concrete, which may be applied with a cement gun, or plastered on expanded metal or other reinforcing; or it may be poured into forms, making a solid mass several inches thick.

Pipes and Wires. Provision must generally be made for carrying water and gas pipes, wires and occasionally sewers and other structures across a stream, either supported by the

bridge or buried in the bed of the stream. If the former, the strength of the bridge must be calculated to support this additional dead load. In the case of a through bridge, the pipe may be carried along the foot of a truss, resting on the floor, and serve as a wheel guard. Or it may be suspended by rods from the pins of the lower cord. In the case of a deck bridge it may be carried under the floor on light cross beams, or brackets fastened to a truss, or suspended from the floor beams. In the case of masonry arch bridges, the best plan is to construct a conduit (large enough for a man to crawl through, if possible) under either roadway or sidewalk, access to which is provided

FIG. 63.—Footbridge over Tracks, Los Angeles. Same as Fig. 17, but protected by encasing in concrete.

for by manhole openings or removable slabs; provision also being made for getting water or gas pipes into this conduit after the bridge is in use.

When a water, gas or other pipe is carried over on the floor of a bridge, the angles between the pipe on the bridge and the riser, and between the latter and the buried pipe, should be reinforced against pulling apart owing to settlement of the buried pipe or vibration of the bridge. Perhaps the best plan is to use, for all pipes in the riser and at its ends, special castings having lugs by which the joints can be held together by bolts. Water pipes carried on bridges should be boxed in or otherwise protected against freezing.

In many cases there will be a storm sewer in the street discharging into the stream, or such may be constructed later;

and the most favorable point of discharge is that occupied by the abutment. An opening through the abutment is then left of the proper size, and the wall around and especially above such opening may be reinforced by steel rods, by steel beam spanning the opening or otherwise. Also the bed of the stream in front of the abutment should be protected from scour by the sewage, by placing there an apron of rip-rap, concrete or other material; and the opening should be set as low as possible to minimize the drop of the sewage and the resulting erosion.

If the bridge, or one span of it, is movable, all pipes must generally be carried in the bed of the stream. Wires may be so carried, in the form of a cable; or the cable may be suspended from high towers, one at each end of the movable span.

Approaches. If the bridge is raised considerably higher than the street at one or each end, it must be reached by approaches having grades not exceeding those suitable for streets. These may continue in the direction of the axis of the bridge, an additional span crossing the marginal street; or this street may be made a two-level one at this point, the upper level connecting with the birdge and joining the lower level by practicable grades in both directions; or both methods may be adopted; or both marginal street and direct approach may be raised and graded up to the bridge for their entire width. The local conditions should be carefully studied, as this matter of approaches has a very important bearing on both the usefulness and appearance of the bridge.

Movable Spans. Where a bridged stream is navigable, it is always best to set the bridge high enough to allow all river craft to pass under it, if this is practicable physically and financially. The delay to traffic caused by an opened drawbridge may become a very serious matter; accidents at such are continually occurring; and the expense of keeping constantly at hand a tender capable to operate the machinery and of keeping this in order is considerable, and may easily equal the interest on $20,000, which amount, plus the additional cost of

the movable span and its machinery, could therefore have been spent in raising the bridge.

FIG. 64.—Lift Bridge, with Counterweights.

Movable spans in common use are of three general types—those which turn in a horizontal plane on a central pier; those which are lifted bodily vertically for any desired distance;

and those which swing up around one end as a hinge. The first have always been and still are probably the most common, especially where there are several spans over a wide river, only one of which needs to open, or where the channel is sufficiently wide to permit a pier in its middle. Where the channel is too narrow to permit a pier in it, either the swing bridge must revolve on a pier placed at the edge of the channel, half of the bridge span being over the land; or one of the other two types is generally used. The lift bridge type has been used by Rochester, Chicago and several other cities; but owing to a number of awkward and serious experiences with disabled mechanism, most cities have discontinued building them, and have adopted the third type, of which the Scherzer rolling lift bridge is best known in this country; although others of the bascule type, revolving on trunnions, are in service. Either the whole bridge may swing up on one end, or two halves swing around the two ends. The third type, bascule bridges, can be opened and closed more quickly than the others and are specially suitable as roadway bridges in cities.

Art. 15. Water Courses and Water Fronts

A small stream, a water front on a large body of water, or a lake or pond will be either an important element in the beauty and attractiveness of a city or in its commercial life, or it will be a repulsive, unhealthful disgrace. Which it is will be determined largely by the foresight and appreciation of the importance of the matter by the citizens and their officials.

A small stream, since it is not wanted in a street, is generally left by the street planners running through the abutting property —frequently forming the rear boundary between properties. Here it receives rubbish of all kinds which will float, ashes and other heavy rubbish are deposited along its banks, privies are set overhanging it, and in general it and its banks become the receptacles for all the dejecta of the houses and their occupants. It would be better to lay out a public way along and including both banks of a small stream of this kind (the stream being

straightened, if necessary), the banks being either graded and sodded, or walled up, and a path or sidewalk placed along each side. Or the stream can be carried in an open channel through the center of a street, with a sodded or planting strip along each side; the channel to be covered over at a future time should the additional street width be desired.

If the stream is very small—merely the outlet of a spring—it can be carried in a specially wide and deep gutter on one or both sides of the street until such time as storm sewers are built which can carry it. Meantime, make frequent measurements of the flow so that the capacity of sewer required will be known when the time comes to build it.

Larger Streams. If the stream flows more than 6 or 8 cu. ft. per second during a large part of the time, there is no question that it should receive special attention, and its banks be owned by the municipality in order to prevent its misuse. There are several towns in the United States each of which is remembered by visitors chiefly for its attractiveness due to the fact that a stream flows through its center whose banks are sodded, trees planted and a walk laid along each bank, and beyond this parking on each side is a roadway on which face business houses and, further from the business center, residences. Such banks should be as flat as 2 to 1 and sodded or paved neatly with stone. Shrubbery is not desirable if the stream has intervals of high water, for this catches all sorts of floating matter such as hay, leaves, rags, paper, etc., and also might be washed out. A well-rooted sod, however, will withstand considerable current, will not catch floating matter, and is easily cleaned when the water recedes.

It would be desirable in some cases to take advantage of a low spot along the stream to enlarge it into a pool, possibly as a wading pool for children, or only to relieve the monotony of the straight, uniform water course.

If there is no effort to make the stream an attractive feature of the town, at least everything practicable should be done to prevent the use of it as a receptacle for all kinds of rubbish. It should be walled in by practically vertical walls; the bottom

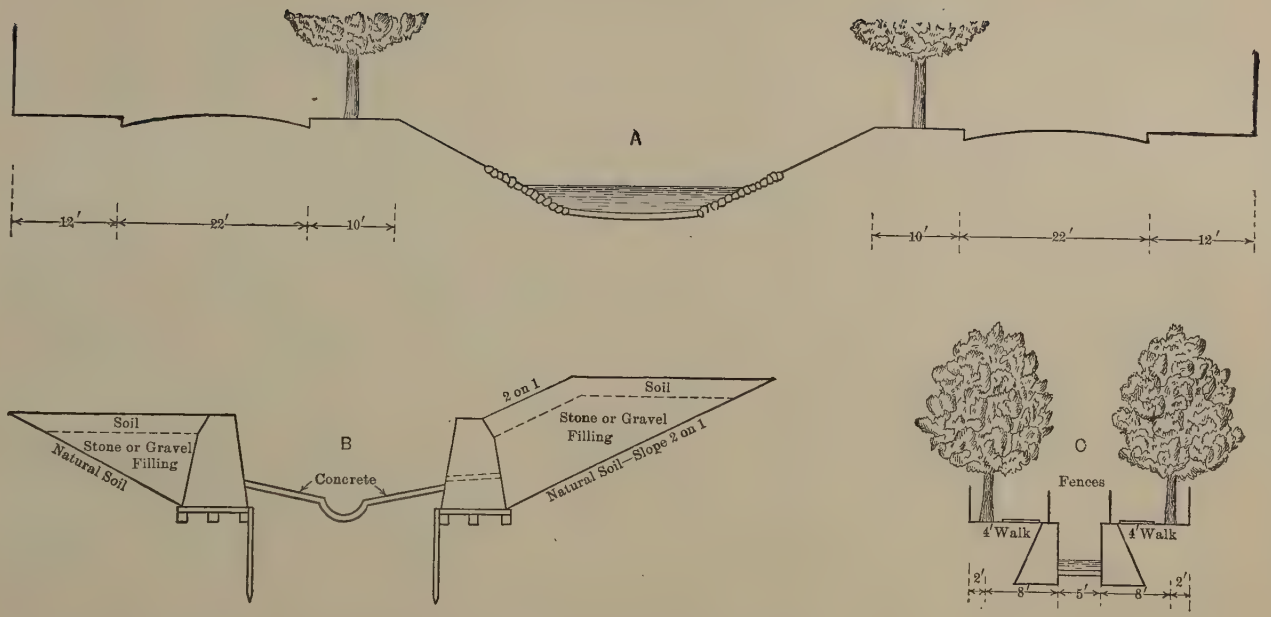


FIG. 65.—Treatment of Streams in Cities.

A, sidewalk, roadway and parking on each side of paved channel with sodded banks. *B*, Retaining walls and paved bed. *C*, Small stream with parked banks between rear fences of private properties.

should be made smooth (as by a concrete lining) to prevent sticks, barrels and other matters thrown in or brought down by floods from being held in any part of it by stones or other roughness or protruding matters; and also to prevent the bottom being washed out by flood, and at the same time give the water as great velocity as possible to reduce the cross-section required to carry the flood and to prevent deposits of silt, gravel, etc. The smooth bed also makes it much easier to remove deposits of any kind, and thus to prevent the gradual raising of the bed and of the resulting ground water and flood levels. Providing a smooth, non-erodable bed is probably the greatest single improvement which could be made to most such streams. If the flow is small in dry weather, it is desirable to give the bottom of the cross-section a flat slope toward a channel, set generally in the middle line of the bed, of sufficient capacity to carry such flow.

When constructing a bottom and walls or otherwise improving a stream, the advisability of lowering it should be considered. It will probably receive the surface water through storm sewers, and the lower it is the more favorable for good grades for such sewers and the less danger that high water will back up onto the streets or low-lying property. Lowering it will also serve in most cases to lower the ground water in its vicinity. The material excavated can sometimes be used to advantage for filling and leveling up low land along the sides of the channel. As the smooth bottom and sides of the channel will result in greater velocities than were found in the unregulated stream, the slope up from the outlet can be reduced with the new construction, thus securing the greater depth.

Mud flats or other low, swampy border lands should be filled in as soon as possible and raised at least 3 ft. above mean water level—ultimately above flood level if possible. Since these flats may have formed part of the flood-water channel it may be necessary to place the river wall or embankment in the middle of the flat, excavating the outer part to increase the channel area and filling the landward side. Such made land is especially suitable for parking, since likely to afford difficult foundations

for building and damp cellars. Dykes or embankments are usually cheaper than walls, but occupy more space. They should be paved at least up to a point a foot or two above normal water level.

The channel of a stream often winds circuitously through low land, and should be straightened when walls or embankments are built. In general the alignment of any stream (except in a park or where the streets follow irregular lines) should be straightened so as to interfere as little as possible with private property or the public use of adjacent land. Where there are bends, they should be made with curves of long radius, never with angles. In business districts especially, it is desirable to straighten and wall the stream, and probably to cover it if it is not too wide.

If walls are built by private parties owning abutting property, the requisite width of channel should be determined and the proper line for a wall fixed, and it should not be permitted to build any wall or carry the foot of any fill beyond this line.

To better insure that the stream shall not be polluted, some cities have constructed a roof resting upon the side walls, thus practically making it a sewer. Baltimore has placed a wide traffic highway on the roof of such a stream and thus secured a much-needed level thorofare. In other cases buildings have been constructed over such covered streams.

Careful calculations should be made and data investigated to determine the maximum flood flow of a stream to be walled or dyked, and the walls so placed as to allow for this. The requisite area of flow must be provided below the lowest girder or wind braces of every bridge, and below the top of wall or dyke if possible. If the flood channel is too wide to bridge with a single span, piers can of course be used, for the roadway embankment should not be carried unbroken so as to block the required channel area. An alternative sometimes employed is to carry the roadway across the bottom land only slightly higher than ordinary river level except at the bridge approaches, paving it with non-erodable material and the slopes with stone;

over which road occasional floods will flow practically unimpeded.

The above refers especially to small streams. If a large stream requires straightening and lowering, the penalty of unwise tampering with existing conditions which a flood may impose is too serious to warrant entrusting this to any but expert advisers.

A *navigable stream* should be parked in the residence section, and provided with docks or piers, or at least walls, in the business. Railroads will generally lie near it because their routes will naturally be in its valley; and factories, because of the low, flat land and the freight facilities by rail and water. These facts should be provided for in the street layout. A street should lie along each bank of the river, as far as possible, giving access to all the docks. Above everything, the city should own and retain possession of every street continued to the river, which will give opportunity for building bridges where needed, or public docks where they are not. As much additional water front as possible should be retained as public property, to be parked or leased for private purposes until needed for docks, being thus under control of the city to prevent encroachments and unsightly treatment.

Water fronts on navigable bodies of water will in time become centers of wholesale transportation, and a marginal street should be laid out along the front and thorofares for freight hauling lead there. If the river be wide enough, provide for piers extending out into the channel for a distance at least 25 per cent greater than the length of the largest boat that can navigate the stream. Bulkhead and pierhead lines should be established; the former the outer limit of the river bank or marginal wall; the latter the line beyond which no piers are allowed to extend. There should remain outside the pierhead line not only sufficient free channel to carry all flood waters, but abundant room for boats to turn on entering or leaving the pier.

The object of a pier is to extend the length of water front along which a vessel can moor; also to protect her from floating ice

and debris, flood waters, etc. Piers are seldom built for the latter reason alone, or when the width of stream is less than 1000 ft.

River walls are generally made of concrete, stone masonry or timber cribbing. An advantage of a timber wall, in addition to its cheapness, is that, during the few years of its life, the flow of the stream can be studied; and when a more permanent wall takes the place of the timber, any changes in width, location or other features which such study has indicated as desirable can be made. A masonry wall should be built before the banks are so built up or improved that a failure of the wall would do serious damage. If the body of water is large, waves may exert great force against the wall, and it should be designed accordingly. Water washing in and out of joints or any small openings exerts a suction which removes any loose mortar or dirt and even will draw the backing from behind the wall through an open joint. Great care should therefore be taken to thoroughly fill all joints, and make their number as few as possible. To effect this and also to oppose the inertia of large masses to the blows of waves, cyclopean masonry or concrete, either in large blocks or in monolithic construction, should be used where there is exposure to the ocean, lakes, wide rivers or other large bodies of water; and large stones with tight joints (no spalling of chinks) or first class concrete for small streams. In constructing the foundation, account must be taken of the weight of the wall, the thrust of the back filling and the scour of the water. Where the water is of practically uniform level at all times (as a great lake or the ocean) the effect of the water in counteracting the horizontal thrust of the back-filling may be allowed for after deducting, say, the top 10 ft. to allow for the effect of receding waves; in ordinary streams no such allowance should be made. Wood can be used up to one or two ft. below the lowest possible level of the water, but above this it may decay.

The best foundation is rock. Gravel is generally reliable if in a continuous stratum of considerable area and thickness; a foundation on this should be carried to a depth below the bed

of the water equal to at least one-third the bottom width of the wall. Hard clay may be used under similar conditions for light walls, if absolutely protected from scour by water either above or underground. When the bottom is soft for any depth, piling is generally the most satisfactory solution, cut off 2 ft. or more under the lowest water. Where the foundation is on any material except rock, sheet piling should be driven along the toe of the wall to prevent scour. If the material is easily eroded, rip-rap or other protection should be placed along the toe. (If the entire bed of the stream is paved, these precautions are unnecessary.) If soft material extends to some depth, a stone-filled crib may be used temporarily as a wall; the permanent masonry wall being built on the portion of this below water level as a foundation, after it has reached final settlement.

River walls are generally made with the width of their base about two-thirds to three-quarters the height of the wall, and the top about one-third. Whenever possible a back-filling of stone, gravel or other very porous material should be placed behind the wall, down to a plane sloping back 45° from the bottom of the wall. Weep holes should be built through the wall near the bottom, just above ordinary water level, every 50 or 100 ft. If the ground back of the wall is higher than the wall, the height of this should be considered, in calculating the bottom width, as being the difference in elevation between the bottom and the point where a line from the rear of the base, at 45° with the vertical, cuts the ground surface.

A timber wall is often made of cribs filled with stone. The width should be about double that of a masonry wall. Squared timbers, with crossties every 5 or 6 ft., the whole fastened at every intersection with drift-bolts and packed with stones. Or a single wall of squared timbers is tied back to piles driven a few feet back of this wall at intervals of 5 or 6 ft. In some cases piles are driven in firm soil and walls of 2-in. or 3-in. plank placed behind them and spiked in place; the piles extending into the soil a distance equal to the height of the wall if the soil be soft, or half to three-fourths of this if it be firm. This is more substantial

if anchored to "drag" piles every few feet, as in the case of squared timber walls.

The material behind a wall is often as important as the wall itself, as far as stability goes. No muck, quick-sand or other material which absorbs water or becomes semi-fluid when wet should be used unless the wall be made extra heavy. If no good material can be found and lumber is cheap, the thrust of soft back-filling may be greatly reduced by building a crib back of the wall, with a thickness equal to its height, dividing this into two or three long chambers by tight longitudinal vertical partitions, and filling this with the best material at hand.

Wharfs and Piers. A wharf is a sea or river wall suitable for boats to lie up to while taking on or discharging cargo or passengers. A pier is a narrow projection from the bulkhead or river wall, against one or both sides of which boats can moor and onto which they can discharge cargo. "If the water front consists of a marginal wall or bulkhead only, its length is the measure of the wharfage room. If piers are built out from a marginal wall or bulkhead, the wharfage room of a given length of water front is increased by double the length of the piers. . . . The pierhead line should be as far out in the river as circumstances and conditions permit. The bulkhead line should be no further out from the shore than is necessary for a marginal street. A marginal street is required inside the bulkhead line to afford the necessary access to and between the piers and the streets leading to the interior of the city." (Eng. in Chief, Dept. of Docks, New York.) Where little wharfage room is necessary, piers would be an unnecessary expense. In narrow streams piers are impossible, since, to permit boats to enter and leave them, there must be at least 4 to 6 times the length of the boat between the pierhead and the opposite side of the channel.

A *wharf* may be a river or sea wall behind which the ground is leveled off for some distance, provided with mooring posts set a little distance back from the wall face. The face of the wall should be vertical or battered about 1 in. per foot. It is desirable that no stone in the face of the wharf be less than $\frac{1}{2}$ cu. yd. in

volume, as the blows of boats too readily move smaller stones from their place. To prevent the stone from abrading the sides of boats, the face of the wall should be dressed perfectly smooth, or else an oak waling piece should be tied to the face of the masonry about 2 ft. above the water surface by bolts whose heads are countersunk. Where there is no heavy river wall, or the expense of one for a wharf is considered too great, a timber wharf may be built. This need not act as a retaining wall, but consist simply of piles supporting a heavy flooring; the water slope of the ground under the wharf should be rip-rapped or protected from

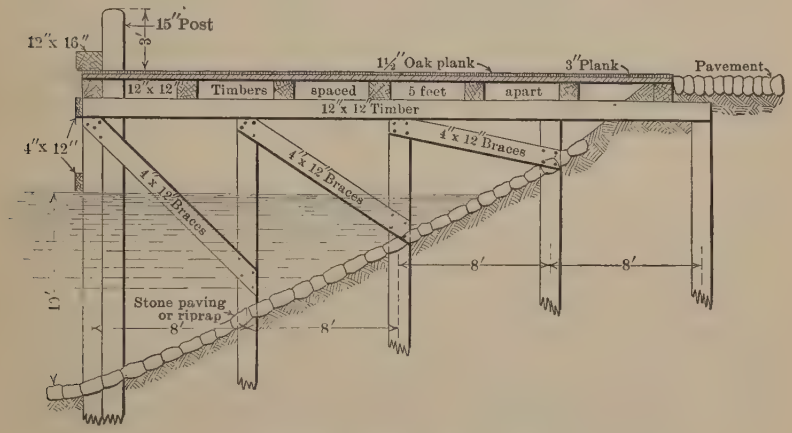


FIG. 66.—Suggested Construction of Timber Wharf.

wash in some way, however, or such wash may in time cause the wharf to be separated from the main land. Waling pieces two or three feet apart vertically should be bolted along the front of such wharf above the water level. The wharf may need to be carried out into the stream some distance to reach deep water.

Piers (as here considered) are heavy floors, well above high water where possible, supported by piles of timber or iron, from 10 to 100 ft. or more wide, projecting into a stream or other body of water; at the ends of which, and usually the sides also, boats can moor. The piles may reach rock, hard-pan or other solid

bottom, or may be held up by friction only, or by mud flotation where there is no solid bottom within practicable depth. Many of New York's piers are floated in the last way, in which construction timber piles are used. The force of flotation of a pile is theoretically the difference in weight of the pile and of the mud and water displaced by it. Assuming the weight of a submerged pile at 50 lbs. per cu. ft., of mud at 100 lbs. per cu. ft., each cu. ft. of pile in mud exerts an upward force of 50 lbs. and in water of $12\frac{1}{2}$ lbs. A pile averaging 10 in. diameter, in 20 ft. of mud and 10 ft. of water would exert an upward pressure of $562\frac{1}{2}$ lbs. on this basis. There will always be more or less friction also, depending upon the density of the mud.* Where flotation is relied upon to any extent, either the wharf or pier should be loaded as uniformly as possible, and the piles distributed uniformly, or the piles at any point should be proportioned to the load to come upon them; and in either case, if gravel or rip-rap be placed on the river bed, it should be given a uniform thickness over the entire area covered by the wharf.

Iron piles are often hollow pipes, sunk by a water jet to solid bottom, and tied together into a framework by diagonal tie rods, both longitudinal and transverse. Cast iron with comparatively thick walls should be used. Sheet iron is sometimes used in the form of large cylinders filled with concrete, which latter acts as the pile when the sheet iron has rusted away.

The flooring of piers is generally of plank, allowing a certain flexibility, since probably no piers except solid masonry ones are without motion during storms or due to blows from boats. Along the outer edges a heavy timber, 8×12 or 10×12, is bolted on top of the floor as a guard. At intervals piles are driven near the edge of the wharf which are allowed to extend about 4 ft. above the floor level for mooring posts; these should be stiffened by tying them to the adjacent piles just under the flooring.

* A pile 90 ft. long, in mud more than 200 ft. deep, in San Francisco upheld 45 tons without the slightest perceptible settlement, or 1000 lbs. per ft. of depth, according to H. C. Holmes in a Report to Bd. of State Harbor Com'rs. of California. This must have been largely skin friction.

Wharf piles are ordinarily driven about 5 ft. apart transversely and 10 ft. longitudinally in New York; 9 ft. transversely and 10 ft. longitudinally in Boston; 15 ft. transversely and 10 ft. longitudinally in Philadelphia, with the addition of clusters of four piles each every 20 ft. longitudinally. These wharves were designed for loads of 400 to 600 lbs. per sq. ft. with a factor of safety of 4. The piles are capped with 12×12, 14×14 or 8×16 timbers, placed transversely, on which rest 12×12 or 12×14 stringers 5 ft. apart, or 6×14 stringers $2\frac{1}{2}$ ft. apart, center to center. The flooring is generally of 3 in. planks of hard pine or oak. Each bent of piles is braced by cross-braces of about 4×8 oak or pine, bolted to each pile. Instead of mooring piles, iron mooring bits are used in New York and Philadelphia, bolted on top of the backing block (or curb) and through the outside stringer.

CHAPTER V

CITY SURVEYING

Art. 16. Precision

No survey ever made can be guaranteed as absolutely accurate; if it is so, it is by chance only. But the probable error can be reduced to almost any desired limit by securing refinements of implements used and of methods employed. Increased accuracy, however, involves the use of more expensive instruments, a longer time devoted to the survey and greater skill and experience, all of which increase the cost. As it would not pay to spend more money on increased accuracy than the land involved is worth, the value of the land will generally determine the degree of accuracy which is warranted.

But it is probable that in time the value will increase, so that an error of 5 ft., allowable in a farm survey when that amount of land was not worth five dollars, may in the future involve land valued at five thousand. Even then the really important point is not the actual length of the original line, but the exact location of the original corner. It is this location which is recognized by law as defining the bounds of a property, and measurements and angles are only means employed for locating and finding it. Therefore monumenting of corners in an original survey is even more important than accuracy in the surveying. This of course applies to original surveys only, and not to resurveys to locate a corner previously established.

But most city surveying is resurveying, and monuments are few and far apart, so that reliance must be placed on measurements to locate property corners. For farm land an error of one to 300 or 500 may be sufficiently accurate; for villages and small towns, one in 5000; while in the center of a large city one in 50,000 may

be necessary. This applies to surveying of lots or blocks; but in making a triangulation or other primary survey an error of one in 100,000 to 500,000 is frequently attained. The figures given refer to the probable error of the mean of two measurements of the same line. It is found by least squares that the probable error of the mean is one-third the difference between the two measurements; or that to secure a probable accuracy of $\frac{1}{50,000}$ in a mean of two measurements, the measurements should not differ from each other by more than $\frac{1}{17,000}$.

For a precision of one in 5000 no corrections need be made for sag or small changes in temperature, the tape may be stretched without a spring balance and the horizontality estimated. The plumb-bob should be used, of course, if the ground is not level. For a precision of one in 50,000 the temperature of the tape should be known within one or two degrees; the pull should be within a pound of the standard, measured with a spring balance; sag should be corrected for unless provided for in standardizing, and the tape should be held horizontal or the difference in elevation of the ends known. A precision of $\frac{1}{50,000}$ requires that angles have no error greater than four seconds.

Art. 17. Instruments and Their Use

Tapes. No surveying in settled communities should be done with a chain, but a steel tape should be used. (Linen or metallic tapes may be used for offsets of 50 ft. or less.) The tape should be tested either by the surveyor himself in comparison with a standard maintained by his city, county or state, or by the U. S. Coast and Geodetic Survey at Washington, which will report the temperature, pull and other condition for which the tape is exactly correct as to length; and its length under other conditions of temperature, pull, etc., can be calculated by rules given in books on surveying. The "invar" tape, made of a nickel-steel alloy, has a coefficient of expansion only one-thirtieth

or less that of a steel tape, and with this, temperature corrections can be neglected for all but the most accurate work. It is desirable for the surveyor to establish a standard of his own as soon as the standardized tape is received, by fixing two points in the floor of the basement of a public building; on the floor of a hall along the base board; on the water table of the straight side of a long building; or by two stone monuments with copper bolts inserted, set immovably in the ground where they will not be disturbed. In the floor, a long copper tack may be driven at each end of the tape and on these the distance marked by a fine line scratched carefully with a knife. Or a thumb-tack may be used with a number of 8-oz. carpet tacks driven around it with their heads lapping over the edge of the thumb-tack to hold it in place and protect it from wear.

A spring balance should be used for accurate work. A level can be obtained attached to the balance, but the author has not found any of these to give sufficiently correct horizontality for the most accurate work.

A *transit* for ordinary city or town surveying should be provided with stadia hairs and a vertical circle. It should read at least to 30 seconds. For the most precise surveying one reading to 20 or even 10 seconds is desirable, with magnifying power of telescope, stiffness, delicacy of adjusting screws and all other parts in keeping. A compass is not used in city surveying; but as a relocation often involves re-running an old farm survey, a compass is very useful in work in towns or suburban districts. For primary triangulation, a theodolite with 10-in. or 12-in. circle, and reading by vernier to 3 seconds or by micrometer microscopes to single seconds, is desirable for the most accurate work; but such will not ordinarily be owned by a city engineer.

Level. For most leveling in city work an ordinary level of high grade is sufficient; but for establishing a system of bench marks and occasionally checking up old ones, precise leveling instruments and methods should be employed. However, in towns and small cities sufficiently exact work can be done with a

good wye or dumpy level if it be in the best possible adjustment and if all precautions be taken for eliminating errors, such as duplicating runs, etc. For setting grade stakes, curb, etc., the level on the transit telescope, if kept adjusted, will ordinarily be sufficiently accurate.

Precise City Survey. At some time in the life of a city, a careful, comprehensive, precise survey of the entire city should be made, and the earlier this is done the less the trouble to property owners, city engineer and all concerned except lawyers. Unlimited trouble is caused by inconsistencies in the surveys of neighboring tracts, by undiscovered errors and other conditions known or unknown which can be discovered and rectified only by a precise survey of the entire city. This should be a complete survey of undeveloped as well as developed areas, which will not only check and connect up previous surveys, but furnish information on which to base future city planning.

This survey will generally consist of at least three divisions: First, a primary triangulation of maximum precision, connecting a few points and embracing the entire area of city and immediate vicinity. Second, a system of smaller triangles tying up a greater number of points scattered throughout the city, which are connected up with the primary triangulation points; this work being of less precision than the primary. Lastly, a series of traverses based upon the triangulation points, by which street lines, property lines and other lines and points are located, and from which offsets for topographical measurements are run.

At least two systems of levels also should be run; one a circuit of precise levels surrounding the city or passing as near the outer boundary as permanent buildings or other locations for bench-marks can be found; then a series of less precise levels connecting bench-marks of the precise levels and used to establish bench-marks throughout the city.

As important as the precise triangulation and leveling is the establishing of permanent monuments and bench-marks which can be relied upon to remain absolutely unmoved, and

thus make permanently available the results of the survey. A few monuments and bench-marks which can be relied upon as being absolutely correct are of greater value than several times the number if each of the latter must be checked by others before their accuracy can be relied upon.

In a town or small city only a few blocks wide and long, the primary triangulation is probably unnecessary. In fact, it may be sufficient to run two lines through the center of the city, approximately at right angles to each other, and each straight or as nearly so as possible; using practically primary triangulation methods as to reading angles and measuring lines; and establishing at least three to five permanent monuments on each line. From these monuments and tied to these lines, others may be run with less precise methods through the streets of the city as traverse lines, beginning and ending at the precise line monuments. As the town grows the precise axes should be extended; in fact, they should be kept ahead of the growth, so that the first street or lot subdivision surveys in each section may be based upon them.

If there are hills around the border of or in the town, or other natural opportunities, triangulation should be begun while the town is still small, primary triangulation points being established outside of the present limits of settlement. Such points are more easily used before buildings surround them; and when they have been established, the earliest surveys in their vicinity can be made precisely coordinated with the rest of the city plan.

Triangulation. This is based on the principle of measuring but one line—a base line—and by the trigonometric solving of triangles, calculating all other distances between points selected as triangulation points. As the final distances may total 50 or 100 times the length of the base line, any error made in measuring this will be multiplied proportionately, and the base line measurement must therefore be made with the utmost precision. A long, straight, level and even surface is desirable on which to measure the base; but a surface which is not level but possesses the other characteristics can be used, the horizontal length being

calculated from the distance measured on the incline and the difference in elevation of the ends.

One of the latest complete triangulations of cities was that made of Cincinnati, Ohio. Two base lines were used, one along the 39th parallel, being one line of a transcontinental triangulation run by the U. S. Coast and Geodetic Survey; the other in the parking along a street, the line being about 7860 ft. long. The line was measured with invar base tapes, used under a tension of 15 kilograms, that used in standardizing it. To mark the ends, 4×4 oak stakes were driven with their tops $1\frac{1}{2}$ to 2 ft. above the ground, on top of which were nailed copper strips on which the tape lengths were marked with fine scratched lines. The grade of each stake was taken and measurements taken from one stake top to another without effort to hold the tape level, the horizontal distance being calculated. Temperatures of the tape were taken, and allowances made for this. This measurement required three days with a large force, the work being hastened to minimize the danger of disturbance of the stakes. Neither end of the line corresponded with a triangulation station, but each end was near one, and the distance between the triangulation stations was calculated and used as the triangulation base.

Of the nineteen triangulation stations, some were on buildings where only small signals were required; others, on open ground, required taller signals. The signals were always built in two parts, entirely separate and independent of each other. The tripod, designed to carry the instrument, was made as rigid as possible; surrounding this was a four-legged structure built to carry the observer, a wind shield, etc., the moving of the observer thus not disturbing the instrument.

All observations were made in accordance with the practice of the Coast and Geodetic Survey, as described in the report for 1911. All discrepancies of triangle closure, side, and length conditions were removed from the primary triangulation by the method of least squares. A little over two months was spent on the calculation.

To furnish a connecting link between the triangulation and the mapping survey, a system of traverse lines was run, in which ordinary transits and steel tapes were used. Each traverse

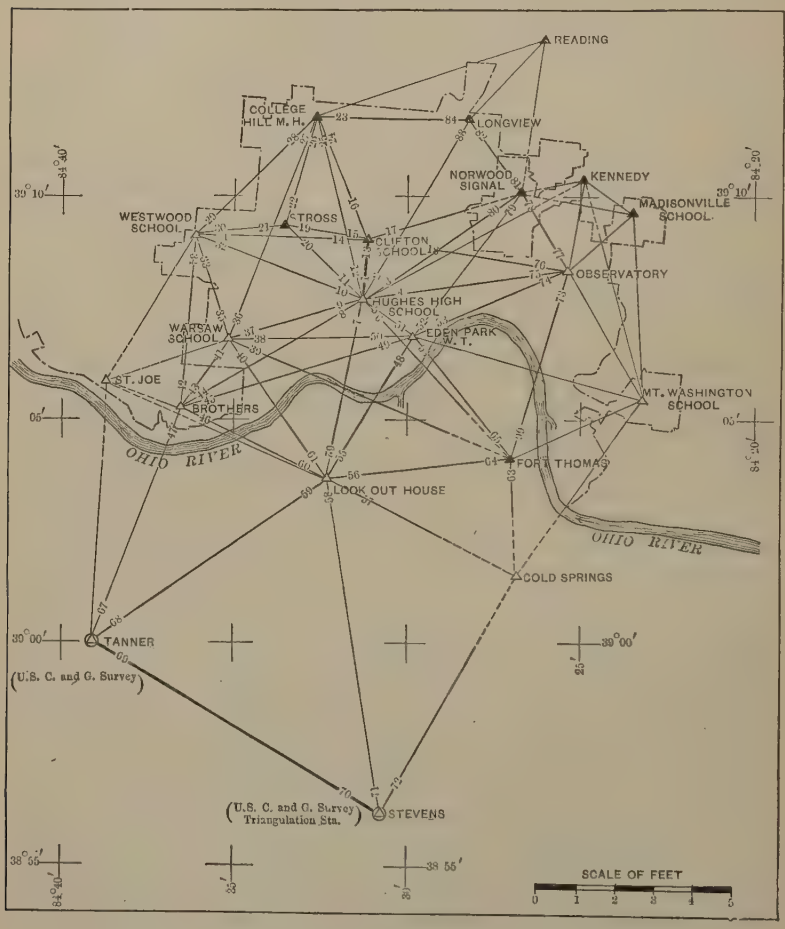


FIG. 67.—Triangulation Net of Cincinnati Topographic Survey.

was run to form a closed circuit. Of two traverse parties, one ran 3.9 miles a week (average) and the average error of closure was 1 in 3380; the other averaged 4.6 miles a week with an

error of closure of 1 in 3580. On an average 10.1 described points were fixed on the ground per mile of traverse.

In the survey of Baltimore, Md., a line of known length established by the Coast and Geodetic Survey was used as a base line, and none was measured. This line was 18,345 ft. long. Each angle was repeated five times from left to right before it was read. The telescope was then reversed and the same angle repeated five times in the opposite direction. The double angle was read in the same manner and each operation was made by two observers; so that each angle was read a total of forty times. Errors were distributed by the method of least squares.

A traverse survey was then run establishing about 5000 traverse points. The surveys were required to close with a limit of error of 1 ft. in 15,000. Angles were repeated three times direct and reverse. A steel ribbon tape was used and the temperature taken and corrected for. A stake was driven at each 100-ft. station and the tape held directly on the stake (no plumb-bobs were used), the tape pulled with a 16-lb. tension and the distance marked on the stake with a pencil. Correction was made for difference of elevations of stakes, and .02 ft. allowed for sag. Levels on the stakes were taken with the level bulb on the transit. Once the corps had become familiar with these refinements, the extra time required over the old method was very little.

For all measuring where any accuracy is desired but not great refinement, and where the ground is not level, measuring on a slope, taking the elevations of the two ends of the tape and calculating the horizontal ordinate is a more accurate method than any practicable one for holding the tape level and plumbing down. Along curbs or sidewalks the tape can be laid on the surface. Where there is grass, however, or the ground is uneven, stakes must be driven at each station, or else the plumb-bob method used. For convenience in correcting for difference of elevation of the ends of a 100-ft. tape, the accompanying table is convenient. As an illustration of its use: If the two ends of a 100-ft. tape, stretched on a uniform slope, have a difference of

elevation of 4.6 ft., the horizontal distance between the ends of the tape is 100 − 0.106, or 99.894 ft.

Table XIX

CORRECTIONS TO BE SUBTRACTED FROM 100 TO GIVE HORIZONTAL DISTANCE, FOR GIVEN DIFFERENCE OF ELEVATIONS OF ENDS OF TAPE

Feet	Tenths of Feet Difference of Elevations									
	0	1	2	3	4	5	6	7	8	9
0	.000.	.000	.000	.000	.001	.001	.002	.002	.003	.004
1	.005	.006	.007	.009	.010	.011	.013	.015	.016	.018
2	.020	.022	.024	.026	.028	.031	.034	.037	.039	.042
3	.045	.048	.051	.054	.058	.061	.065	.068	.072	.076
4	.080	.084	.088	.093	.097	.102	.106	.110	.115	.120
5	.125	.130	.136	.141	.146	.151	.157	.162	.168	.174
6	.180	.187	.193	.199	.205	.211	.218	.225	.232	.239
7	.246	.253	.260	.267	.274	.281	.289	.297	.305	.313
8	.321	.329	.337	.345	.353	.362	.370	.379	.388	.397
9	.406	.415	.424	.433	.443	.452	.462	.472	.481	.491
10	.501	.511	.522	.533	.542	.553	.563	.574	.585	.596
11	.607	.618	.629	.641	.652	.663	.675	.686	.698	.710
12	.723	.735	.747	.760	.772	.785	.797	.810	.822	.835
13	.849	.862	.875	.888	.902	.915	.929	.943	.957	.971
14	.985	.999	1.014	1.028	1.042	1.057	1.072	1.086	1.101	1.116
15	1.131	1.146	1.162	1.177	1.193	1.209	1.224	1.240	1.256	1.272
16	1.288	1.305	1.321	1.338	1.354	1.371	1.388	1.404	1.421	1.438
17	1.455	1.473	1.490	1.508	1.525	1.543	1.561	1.579	1.597	1.615
18	1.633	1.651	1.669	1.688	1.707	1.726	1.745	1.764	1.783	1.802
19	1.822	1.841	1.861	1.880	1.900	1.919	1.939	1.959	1.979	1.999
20	2.020	2.041	2.062	2.083	2.103	2.124	2.145	2.166	2.187	2.208

The precision of angular and linear measurements should be consistent—that is, the percentage of error should be the same in each. Not only this, but if (as is usually the case) the trigonometric functions of the angles are employed in using the angle readings, the accuracy of the functions to be used should be proportional to that of the linear measurements. This will depend on the size of the angle. The following table gives the limit of error permissible for different angles with different precisions of linear measurement.

Thus, if the linear measurements are made with a precision of $\frac{1}{10{,}000}$ and it is not known whether sine or cosine is to be used

TABLE XX

EQUATING ERRORS BETWEEN ANGULAR AND LINEAR MEASUREMENTS

Ratio of Precision	Linear Error in 1000 Ft.	Corresponding Error for Different Angles															
		10°		20°		30°		40°		50°		60°		70°		80°	
		Sin	Cos	Sin	Cos	Sin	Cos	Sin	Cos	Sin	Cos	Sin	Cos	Sin	Cos	Sin	Cos
1/20,000	.050 ft.	2″	1′ 0″	4″	30″	6″	20″	8″	13″	13″	8″	20″	6″	30″	4″	1′ 0″	2″
1/15,000	.067 ft.	2″	1′ 0″	5″	40″	10″	20″	10″	15″	15″	10″	20″	10″	40″	5″	1′ 0″	2″
1/10,000	0.10 ft.	4″	2′ 0″	10″	1′ 0″	10″	40″	15″	25″	25″	15″	40″	10″	1′ 0″	10″	2′ 0″	4″
1/5000	0.20 ft.	7″	2′ 0″	15″	2′ 0″	20″	1′ 0″	30″	50″	50″	30″	1′ 0″	20″	2′ 0″	15″	2′ 0″	7″
1/2500	0.40 ft.	15″	3′ 0″	30″	2′ 0″	50″	2′ 0″	1′ 0″	1′30″	1′ 30″	1′ 0″	2′ 0″	50″	2′ 0″	30″	3′ 0″	15″
1/1000	1.00 ft.	30″	5′ 0″	1′ 0″	4′ 0″	2′ 0″	3′ 0″	....	3′ 0″	3′ 0″	2′ 0″	3′ 0″	2′ 0″	4′ 0″	1′ 0″	5′ 0″	30″

in the calculation, or both are to be used, angles of about 10° should be read with a maximum error of 4″, those of 40° with a maximum error of 15″, those of 70° with a maximum error of 10″, etc.

Precise Leveling. For the most accurate leveling a precision level is used. The general features distinguishing the modern precision level is that the level vial is constructed close to the line of collimation, set into the telescope tube and not attached to it by a post at each end as in the ordinary level; the reason for this being that it more certainly insures that vial and line of collimation will not be changed in their relative position by temperature changes in the instrument. There are no wyes, the general construction being that of a dumpy level. The other peculiarity is that, by means of mirrors and a second eyepiece and tube, the observer is able to see the bubble with one eye and the rod with the other, simultaneously; thus insuring that the instrument is precisely level at the exact instant of reading the rod. To further minimize the temperature changes in the instrument, the metal used is a nickel-iron alloy. The level vial is of the chambered type and is filled with pure sulphuric ether. One vertical and three horizontal hairs are used, the three latter being equidistant.

The rods are single sticks of pine of cross-shaped section, rendered impervious to weather by boiling in paraffine. The shoe of the rod is made of the hardest bell metal, with a rounded or hemispherical-shaped bottom with a radius of one inch. For turning points, a cast iron disk 6 in. in diameter containing in its top surface a cavity with a radius of $1\frac{1}{4}$ in. is used; or a pin of hard steel $9\frac{1}{2}$ in. long having in its top a similar cavity. The disk has three or four points in its under surface which are driven into the ground to hold it. The pin is driven into the ground with a mallet, and is preferable for grassy soil or other which has not a firm surface. For street work neither is necessary, curb or roadway or sidewalk pavement being used, the exact point on which the foot of the rod rests being marked by a crayon.

By no means the least important part of a precise leveling outfit is a large canvas umbrella, preferably colored, such as a "beach umbrella." Even with an ordinary level, more precise results may be obtained if the instrument is shaded. Better still is it to do all leveling in cloudy weather but when the air is clear; but this of course is not always possible.

Bench-marks should be established at intervals of one-half

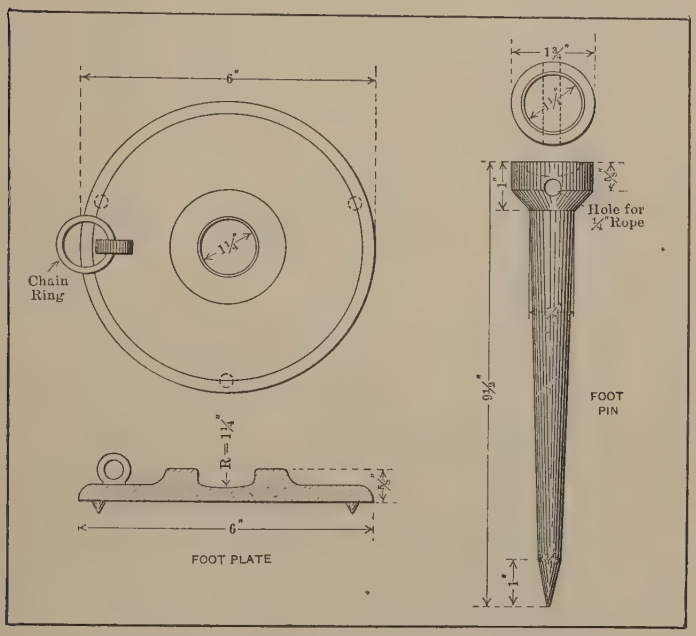


FIG. 68.—Foot Plate and Foot Pin for Precise Leveling.

mile to one mile along every line of levels, and at even shorter intervals throughout the center of the city. Each line should be re-run backward (in the opposite direction), preferably under different atmospheric conditions from those which occurred on the forward leveling.

The following are the instructions given to precise leveling parties of the U. S. Coast Survey. For careful leveling with an ordinary level to establish or check up city bench-marks, these

rules should be followed so far as they are practicable with the instruments used.

General Instructions for Precise Leveling

1. Except when specific instructions are given to proceed otherwise, all lines are to be leveled independently in both the forward and the backward direction.

2. The line of levels is to be broken up by bench marks into sections from 1 to 2 kilometers long, except where special conditions make shorter sections advisable.

3. All old bench marks are to be called by their old names and are to be fully described by quoting the old description, if one is available, and by making additions to it.

4. It is desirable that the backward measurement on each section should be made under different atmospheric conditions from those which occurred on the forward measurement. It is especially desirable to make the backward measurement in the afternoon if the forward measurement was made in the forenoon, and vice versa. The observer is to secure as much difference of conditions between the forward and backward measurements as is possible without materially delaying the work for that purpose.

5. On all sections upon which the forward and backward measures differ by more than $(\sqrt{K})\ 4_{mm}$. (in which K is the distance leveled between adjacent bench marks in kilometers), both the forward and backward measures are to be repeated until two such measures fall within the limit.

6. Whenever a blunder, such as a misreading of 1 decimeter or of 1 meter, or an interchange of sights (the backsight being recorded as a foresight) is discovered in any measure after its completion, and the necessary correction applied, such measure may be retained, provided there are at least two other measures over the same section which are not subject to any such uncertainty.

7. The program of observation at each station is to be as follows: Set up and level the instrument. Read the three lines of the diaphragm as seen projected against the front (or rear) rod, each reading being taken to the nearest millimeter (estimated), the bubble being held continuously in the middle of the tube (i. e., both ends reading the same). As soon as possible thereafter read the three lines of the diaphragm, as seen projected against the rear (or front) rod, estimating to millimeters as before, and holding the bubble continuously in the middle of the tube.

8. At each rod station the rod thermometer is to be read to the nearest Centigrade degree and the temperature recorded.

9. At stations of odd numbers the backsight is to be taken before the

foresight, and at even stations the foresight is to be taken before the backsight.

10. The maximum difference in length between a foresight and the corresponding backsight is to be 10 meters. The actual difference is to be made as small on each pair of sights as is feasible by the use of good judgment, without any expenditure of time for this particular purpose.

11. The recorder shall keep a record of the rod intervals subtended by the extreme lines of the diaphragm on each backsight, together with their continuous sum between bench-marks. A similar record shall be kept for the foresights. The two continuous sums shall be kept as nearly equal as is feasible, without the expenditure of extra time for that purpose, by setting the instrument beyond (or short of) the middle point between the back and front rods. The two continuous sums shall not be allowed to differ by more than a quantity corresponding to a distance of 20 meters.

12. Once during each day of observation the error of the level should be determined in the regular course of the leveling and recorded in a separate opening of the record book, as follows:

The ordinary observations at an instrument station being completed, transcribe the last foresight reading as part of the error determination, call up the back rod and have it placed about 10 meters back of the instrument, read the rod, move the instrument to a position about 10 meters behind the front rod, read the front rod, and then the back rod. The rod readings must be taken with the bubble in the middle of the tube. The required constant C to be determined, namely, the ratio of the required correction to any rod reading to the corresponding subtended interval, is

$$C = \frac{(\text{sum of near rod readings}) - (\text{sum of distant rod readings})}{(\text{sum of distant rod intervals}) - (\text{sum of near rod intervals})}.$$

The total correction for curvature and refraction must be applied to the sum of the distant rod readings before using it in this formula. The level should not be adjusted if C is less than 0.005. If C is between 0.005 and 0.010 the observer is advised not to adjust the level, but if C exceeds 0.010 the adjustment must be made. If a new adjustment of the level is made, C should at once be redetermined. It is desirable to have the determination of level error made under the ordinary conditions as to length of sight, character of ground, elevation of line of sight above ground, etc. The level must be adjusted by moving the level vial, not by moving the reticle.

13. Notes for future use in studying leveling errors shall be inserted in the record, indicating the time of beginning and ending of the work for each section, the weather conditions especially as to cloudiness and wind, and whether each section of the line is run toward or away from the sun; and such other notes as may be of value in studying errors.

14. The instrument shall be shaded from the direct rays of the sun, both during the observations and the movement from station to station.

15. The maximum length of sight shall be 150 meters, and the maximum is to be attained only under the most favorable circumstances.

16. At the beginning and end of the season and at least twice each month during the progress of the leveling, the three-meter interval between metallic plugs on the face of each level rod shall be measured carefully with a steel tape, which shall be continuously kept in the party throughout the season for that purpose. The rod temperature at the time of each of these measures must be recorded. The purpose of these measures is to detect changes in the length of the rods rather than to determine the absolute lengths. The absolute lengths are determined at the office between field seasons. At least once each month, during the progress of the leveling, the adjustment of the rod levels shall be tested and a statement inserted in the record showing the manner in which the test was made, whether the error was found to be without the limit stated below, and whether an adjustment was made. The test must determine the inclination of the rod to the vertical, measured in the plane of sight from the instrument to the rod, as well as at right angles to that plane, when the bubble of the rod is held at the center. If the deviation from the vertical exceeds 10 millimeters on a three-meter length of the rod, the rod level must be adjusted.

Bench-marks are apt to change in elevation or to be destroyed, and every year or two existing ones should be checked and substitutes for missing ones located. This is especially desirable before the beginning of any extensive sewer or paving work. If the Geodetic Survey or other government department has any bench-marks in the city or vicinity, it is desirable to use these, ascertaining their elevation from the department officials. But if there is more than one they should be checked with each other, as these also are liable to slight changes in elevation. If the datum plane to which the elevation of all bench-marks is referred be assumed, it is desirable to take such elevation that the deepest sewer in the lowest part of the city will not have a negative elevation. This is generally secured by making the datum say 10 ft. below low water at the lowest part of any of the neighboring streams or ponds within several miles of the city (to allow for growth of the city and for a sewer outlet being carried beyond city limits).

For carrying a line of levels across a river the following, known as the simultaneous reciprocal method, is recommended:

Two levels and two rods are used, one of the levels being set up on each side of the river about 20 ft. distant from the B. M. or T. P. A rod reading is then taken by each observer on the B. M. or T. P. nearest his instrument; then, at a given signal, the observations are commenced and the targets are set on each of the distant rods at nearly the same instant, and the reading recorded. Simultaneous observations are therefore made in opposite directions by each observer.

This operation is repeated ten times, allowing about five minutes between successive readings so as to permit of a change in the atmospheric conditions. The near rod is read only at the beginning and at the end of the program of observation. The observers then exchange stations, each man taking his instrument with him; the near rods are again read, and at a prearranged signal the observations on the distant rods are repeated in the opposite direction exactly as before. The arithmetical mean of each set of readings is taken as the final result.

When employing this method, it is very essential that both the instruments used should be very nearly alike in the magnifying power of their telescopes and in the sensitiveness of their spirit levels. It is also essential that the two targets be set as nearly simultaneously as possible in order that the same atmospheric conditions may affect both sights. The disturbance of the atmosphere is very great near the surface of land or water, but decreases rapidly with the elevation of the line of sight above the surface. Therefore set the levels and rods so that the line will be at least 10 ft. above the water, and higher if possible. In a 2500 ft. sight across water a difference of .04 ft. between any two readings should cause the rejection of one of them.

The accurate surveys and levels run as described furnish points throughout the city which serve as a control for other surveys less accurately run. These points, set with precision and fixed by immovable monuments, are to be used as starting and ending points of transit and level lines in ordinary work.

The precise points are supposed to have no error in any decimal place used by the less accurate survey. For instance, if the precise level bench-marks have a maximum error of .004 ft., they are correct for any hundredths figure, and ordinary levels run between two precise bench-marks, read to hundredths only, should check exactly on the finishing bench-mark.

Notes. In leveling, turning points should be marked with a colored crayon, either with a cross, or a square around the foot of the rod. This insures using exactly the same point for back- and fore-sights or if the rodman must move for a team, etc.

It has been demonstrated by experience that a railroad rail will return to exactly its former elevation almost immediately after a train has passed over it, and therefore can be used as a turning point.

Asphalt pavements should not be used in any but cold weather, but a nail driven into asphalt down to the foundation (2 to 4 in., usually) can be used. A level or transit will settle if set on asphalt in hot weather.

It is almost impossible to do accurate instrumental work when the ground is frozen or there is snow or ice on it; although if the instrument can be set and turning points taken on cleaned stone or concrete sidewalks and curbs, and great care be taken to see that there is no frost under tripod leg or rod, it may be done.

When possible, an instrument set on a sidewalk should have no leg resting on the stone on which the observer stands. When leveling along a railroad, the instrument may be set with two legs resting on the flanges of the two rails and the third on a tie, on which tie the observer should never step. On busy streets much time can be saved if the level (it can seldom be done with the transit) can be set on steps or other elevated spot so that the line of sight passes over the pedestrians' heads. Where there are stores with show windows, near the curb line is generally freer from interruption than any other part of the sidewalk. Where there are no such windows, next to the building or fence is generally the best place to run a line, especially if there are steps extending out to obstruct pedestrian traffic.

A self-reading rod will expedite profile and cross-section work and is sufficiently accurate for this; the H. I. being checked at every bench-mark available when running profiles. In profile levels, elevations should be taken along the center line of the street and along both curbs or sides; generally at intervals of 100 ft. and at intermediate points where grade changes, at streams, railroads and other special surface features.

The ordinary surveying done by a city engineer's office differs little in general methods of performance from that required for other purposes, except as to precision; and this should be varied intelligently to correspond to requirements and conditions. In running profiles of an ordinary road to be used in planning street grades or sewers, rod readings to the nearest tenth will be sufficiently close; but in running the grade of a railway track or improved street, hundredths are needed to permit a definite idea of the same. In running street lines and setting monuments on the same, a precision of one in 50,000 should be obtained; and all such work should be checked by at least one and preferably by more determinations of each important point located.

Street Lines. One of the most important classes of work performed by the city engineer is the establishing of street lines. Where this has not been done previously, he will probably find encroachments, and must be able to back up his reports on such from a legal as well as a surveying standpoint. The only sure method is to make a complete survey of the city, locating exactly every fence, monument or other object which may have a bearing on determining where the street line was originally located or accepted. The records should then be studied and all inconsistencies between these and the actual conditions noted. (They will generally be numerous.) The laws and court rulings of the state in question must be thoroughly understood; and in the light of these, an effort made to establish the lines as they will be accepted by the courts.. It is the lines as they were, on the ground, and not as they were more or less definitely described, which are upheld by the courts.

In re-running street lines, it is seldom possible to sight a transit or measure directly on the line itself; but a line approximately parallel to this is generally run, points on this near corners or other important parts of the street line fixed by stakes accurately located; and the transit is then set on these and the corners located by angle and distance from this transit line. If the coordinate method is used, the coordinates of each point so located can be calculated from those of the transit points by simple trigonometric calculations. (See Art. 19.)

The commonly accepted procedure relative to determining the location of old lines and corners can be found in books on surveying; these applying also to the lines of private property, distribution of errors, etc. The corners as relocated having been accepted by agreement or affirmed by law, they should be permanently marked by monuments. The street lines should be made continuous from block to block, if possible. If the lines as re-established are not so, it may be possible to make them so and eliminate jogs by consent of property owners or by purchase of narrow strips by the city. Monuments are most important at each angle or jog in the street line.

Re-running division lines between properties where the street is soldily built up often requires special methods, ingenuity and great care. If it is possible to see through doors or windows from street to back yard, a line may be run from a point on the transit line in the street, through the house to the interior of the block, and the corners in the interior surveyed from this. If possible two such lines should be run, one near each end of the block. It may even be necessary to fix points on the flat roofs of houses on an offset of known direction from the transit line in the street, and, setting up on one edge of the roof and sighting on the other, continue this line across the roof and onto the ground in the interior of the block; similarly carrying another line at right angles to this, and intersecting it, from a transit line in an intersecting street; the location of the intersection of these lines being determined by calculation.

Original location of street lines is comparatively simple, re-

quiring only precision in the use of ordinary surveying methods. But the survey should start from and close on monuments of known reliability; preferably those established directly by a precise triangulation or other survey. This survey should determine the length of each side of each block; the widths of streets; angles at each corner or angle in the roadway, or between tangents to curves in the street line (the location of P. C. and P. T. being given). Each angle, P. C. and P. T. in the street line should be monumented. (If monuments are placed on an offset from the side line of the street, it is best to make the survey on such offset line.) The radius of each curve, all the distances mentioned, and location of each monument set, should be clearly stated in the description and shown on the map of the survey which are placed on record.

Where the street lines consist mostly of curves, the survey should be made and monuments established on the tangets to the curves (or the chords, where this is more practicable), and not on the curves themselves; these being laid out, when necessary, by a secondary survey. In some cases tentative lines, including curves, are run more or less hastily and fitted to the ground; and then the lines so determined are run by the more precise survey as described.

The lines being fixed, a profile of the street is generally desirable, elevations being taken along the center and each side line of the street at intervals generally of 100 ft., or 50 ft. if the ground is very uneven. These are plotted on profile paper (Plate A paper, with 20 ft. to the inch horizontal and 4 ft. vertical, is suggested), and the grade of the street planned from this.

Setting grade stakes for curbs has already been described. In setting them for paving, stakes are set on the crown line (which is preferably the center of the street) at intervals of 20 or 25 ft. Opposite each of these is set another stake at each curb line. Each of these is driven until its top is at the grade of the finished pavement; or such grade is marked on the stake, if preferred; although a more common plan is to write on the stake the cut from its top to grade (Example: "C 1 ft.

$2\frac{1}{2}$ in.") or the fill to grade (Example: " F o ft. $6\frac{1}{4}$ in."). In marking stakes for contractors always give inches, not tenths of a foot. In most cases three other stakes on each side, between crown and curb at equal distances (the " quarter points "), are set and similarly marked; and in wide roadways more may be set, with not more than 10 ft. between them. A good plan, if the roadway is not more than 30 or 40 ft. wide, is to have a stiff board template of a half section of the roadway surface; then, by resting this on the grade at crown and curb line, the exact surface of the roadway is obtained, and the sub-grade can be obtained by measuring down from this.

In setting the stakes, if those at each end of a continuous grade are set first, the others may be set by plunging, as described for curbs.

Contour Maps. A survey of the undeveloped parts of the city from which a contour map can be plotted which will show the topography of all such areas is very desirable. In his work on surveying, J. B. Johnson, C. E., late dean of the College of Engineering of the University of Wisconsin, says, " An accurate topographic map of its entire area is one of the most valuable possessions a city can have, for the reason that it makes possible the most economic location and construction of its sewers, water supply and street improvements. The true importance of such surveys has only tardily been recognized by American cities, but in Europe nearly every city bases its extensions upon such surveys. Without such maps a city is forced to design its improvements piecemeal, with the result that they later have to be changed, abandoned or operated at a loss. Great economies result from combining the topographic work with a complete property or cadastral survey."

The figures obtained in making such survey are used for plotting only, and therefore no greater accuracy is required than can be shown by the scale adopted. If the scale is 200 ft. to the inch, for instance, and the lines on the map cannot be plotted or read more closely than $\frac{1}{50}$ in., an error of 4 ft. in a measurement could not be shown or detected. The survey-

ing work therefore need not be very accurate. Stadia and vertical angles for difference in elevation may be used instead of leveling, and stadia for horizontal distances. The plane table can in many cases be used to advantage.

Whatever method or methods be employed, a line of survey should start from a point of precisely known position and elevation, and should end at, and check on, another with an error not greater than the scale of the map warrants. A closed traverse should be run accurately around the area to be surveyed, and others across it if necessary, to establish a sufficient number of fixed points for control of the topographical survey. Lines of levels to establish bench-marks should be run for the same purpose. Either the plane table, transit-stadia method, or division into squares may be used. The first is especially applicable to rough, rolling country and small scale, but can be used to advantage on almost any kind of topographical surveying. The transit-stadia method requires less time in the field; but more in the office than the plane table. The square method is applicable only to uniformly sloping or gently rolling country. The most accurate method is to find points on each contour by the level and run a traverse through them by transit, thus locating each contour separately; but the cost and time required for this are seldom warranted.

Art. 18. Monuments and Bench-marks

Monuments are stones or other fixtures set for the purpose of permanently marking the location of a point—generally the boundary of a street or a property. Bench-marks are special fixtures or points taken on buildings or other structures for the purpose of permanently establishing a point of known elevation. Both should be of indestructible material—stone, bronze, etc. Monuments should be so set as to be immovable horizontally, and bench-marks should be secure against vertical movement, by any settlement or drying out of the ground, or anything other than maliciousness or "acts of God."

Monuments. The most common form of monument is a stone not less than 6 in. across at the bottom and 30 to 40 in. high, with the top dressed square, 4 to $4\frac{1}{2}$ in. on a side, and with the top surface level. A hole drilled in the top surface, or two lines crossing at right angles cut into such surface, mark the point. Granite, fine-grain sandstone or other *durable* stone should be used. The monument is the only record for succeeding generations of the work of triangulation or other less accurate survey, and the ultimate life and value of such survey may therefore be enormously diminished by using as such record a monument of short life.

The stone is set in a hole dug as nearly its size as possible at both top and bottom. A sharp bar and post-hole shovel are generally used, or a large post-hole auger. While the top of the stone is held in position, the hole is filled around it; and this is a most important part of the work. If the soil packs easily and solidly it may be used for this purpose, but the tamping must be most thorough. The dirt is thrown in one shovel-full at a time, and thoroughly tamped with a heavy tamper with a small face—the top of the steel bar used for loosening the dirt in digging the hole serves excellently. The dirt should be slightly damp, but not wet. No stone larger than a walnut should be used in backfilling and very few of these. If such dirt is not available, a lean concrete may be used, and is to be preferred in any case. Either broken stone or clean gravel may be used, and the concrete mixed say 1 : 3 : 6; but the materials should be thoroughly mixed and tamped.

Instead of stone, concrete is often used for monuments, either made in shapes and set like a stone, or filling the entire hole as dug. One used by the Kennebec Water District, Me., was built in post-holes 5 ft. or more deep, made with an 8-in. auger and enlarged at the bottom to 12 or 14 in. diameter with a shovel. A wooden form made to bolt together and give a square top 6 in. on a side for a depth of 16 in. was set in the top of the hole and the concrete was then shoveled in. After a few shovel-fulls were in, two reinforcing bars of $\frac{1}{4}$ in. steel

bent into the form of a long U were inserted so that one leg came at each corner and the short cross-piece a little below the top of the monument; and the rest of the concrete was shoveled in and tamped, the top was smoothed off and an iron casting with expanded bottom set into the top face, this bearing appro-

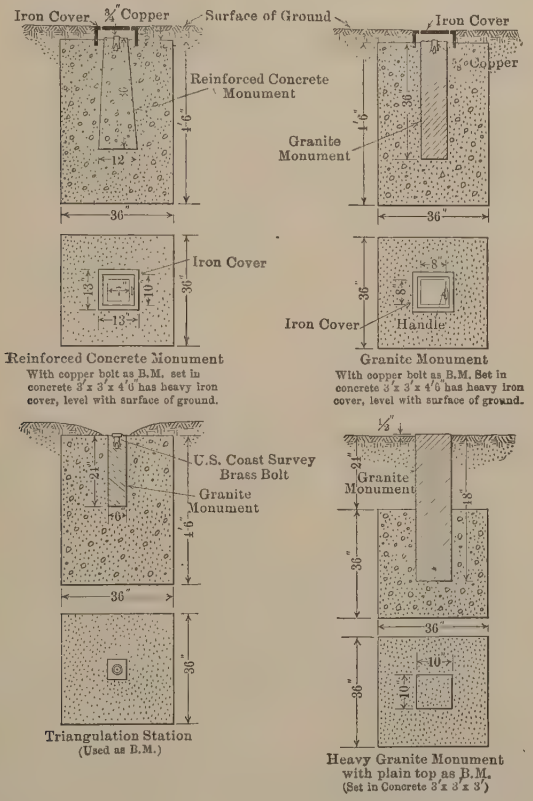

Iron Cover
¾" Copper
Surface of Ground
Reinforced Concrete Monument
Iron Cover
Copper
Granite Monument
Iron Cover
Handle
Reinforced Concrete Monument
With copper bolt as B.M. set in concrete 3' x 3' x 4'0 has heavy iron cover, level with surface of ground.
Granite Monument
With copper bolt as B.M. Set in concrete 3' x 3' x 4'0 has heavy iron cover, level with surface of ground.
U.S. Coast Survey Brass Bolt
Granite Monument
Triangulation Station
(Used as B.M.)
Granite Monument
Heavy Granite Monument with plain top as B.M.
(Set in Concrete 3' x 3' x 3')

FIG. 69.—Standard New York Monument Bench Marks.

priate letters and the number of the monument. The concrete was mixed 1 : 2 : 4. The total cost was about $4.30 each. (Mun. Journal, XXVIII, 58.)

Another method of using concrete is to fill the hole (dug with an auger 3 or 4 ft. deep) with rich concrete, placing therein

an iron or bronze rod whose top is flush with the top of the concrete and in the exact point to be monumented. In Albany, N. Y., 6 ft. or 8 ft. lengths of old steel rails have been used. In Altenberg a cast iron pin is used 60 cm. long, 8 cm. square on top and 4 cm. square immediately above the point. The top is rounded and contains a tapering hole 3 cm. in diameter and 17 cm. deep. This is driven into paved streets with the top 15 to 20 cm. below the surface. Over it is placed a small octagonal iron box with a lid opened by a key, the box being flush with the pavement. This is also used as a bench mark. In fact, almost any monument may be so used, as it is solidly set; but if the top is flat, one corner (designated by chisel mark or otherwise) should be selected.

Salem, Ore., some years ago adopted the use of two stones, one set above the other. The lower one is 5 in. square and 10 in. long; the upper one 5 in. square and 24 in. long. The lower one is set, a chiseled cross in its top surface being centered. When this has been solidly tamped, a quart of charcoal is spread over it and the upper one is bedded in this and similarly centered with its top flush with the surface. The top one is thus convenient for use; the bottom one is protected from disturbance to serve as a permanent record.

In most cities the monuments are set flush with the sidewalk when within the sidewalk strip; in some they are flush with the roadway surface when in the roadway. In the latter location, however, it is much safer to set them about a foot to 15 in. below the surface so that they will not be battered by traffic or disturbed by paving or repaving operations; and cover them with a box, larger than the monument so that it does not rest upon it. A waterworks valve box could be used, but a special one, square and 2 or 3 in. larger than the top of the monument, 12 to 15 in. deep and with outer flanges on the bottom, is preferable. As an additional precaution against disturbance, the hole in which the monument was set may be filled with good concrete which is brought up about a half inch above the top of the monument and smoothed off to serve as a bearing for the

flange of the box. If this and the bottom of the flange are made smooth, the box can slide (as motion of the pavement may compel it to) without disturbing the monument.

The *location* of monuments varies widely in different cities. In a few they are placed at the intersection of street centers; in others at offsets from such centers. Some place them at the intersection of street side lines (street corners). But perhaps the majority place them at an offset from the street line, this offset being uniform throughout a given city, the distances in different cities varying from 18 in. to 8 ft.

As most sewers are constructed in the center of the street, a monument so located is almost necessarily removed during sewer construction, and can not be replaced because the sewer manhole is placed there. In a large city the entire roadway is subject to disturbance for placing pipes or conduits of various kinds. For this reason the author prefers placing monuments in the sidewalk area.

Where there are no fences and the buildings are all set back from the line, the intersection of street lines may be used. But at any time in the future a building or fence may be erected at the corner, which destroys this monument. Therefore an offset is desirable. The least distance from a fence or building at which a transit can be set up without difficulty is about 18 in. The distance should not be so great as to come in line with the trunks of any existing or future shade trees, lamp posts, trolley posts, etc. In the author's opinion there are two objections to placing the monument in the sidewalk pavement—danger of disturbance owing to motion of the pavement or work in constructing or reconstructing it; and sighting between monuments when setting them or when using them later is more subject to interference by pedestrians than if they are in the sodded strip between the pavement and the side line. The latter position, where there is such sodded strip, therefore, seems most desirable.

In either case, the top of the monument is generally placed flush with the sidewalk. If the pavement surrounds or is close

to it, a space of at least a half inch should be kept between the monument and any part of the pavement and filled with sand, to prevent disturbance of the monument by temperature or other movements of the pavement. A better plan, where the monument is in the pavement space (and this becomes necessary, of course, when the pavement extends from side line to curb), is to set the top of the monument about 6 in. below the sidewalk grade, and over it set a plug of cut stone or concrete, $5\frac{1}{2}$ in. deep, about 4 in. square on the bottom, and 3 or 4 in. wider than this on top. A hole to receive this plug is cut into a flagstone pavement or molded in a concrete one, so that the plug sets flush with the pavement; two depressions being made on opposite sides of this hole to receive two pinch bars used for raising the plug, or a ring being set in the center of the plug.

There are two general ways of setting a monument—by transit and tape (or two transits set up on the intersecting lines) direct; or by setting a stake direct, and afterward replacing it with the monument. The former is the more accurate, but greatly delays the precise survey by which the monumented point is located. If it is employed, it is desirable to locate the point to be monumented approximately beforehand, have the hole dug and the monument ready to set, so that the delay of the transit party may be as short as possible. The transit and tape should be used to check the location after the backfilling around the stone and tamping of the same have been completed.

The stone may be set and backfilled, and the exact point then cut on its top; but it is better (although a little more trouble) to have the chisel cut or drill hole made in the center of the stone beforehand and bring this to the exact point.

If the point is marked by a stake and this replaced later by a monument, the following is the ordinary procedure: four stakes are driven, each 3 to 6 ft. away from the monument stake and so located that two strings stretched between them in pairs will intersect exactly at the point to be monumented,

and make an angle of about 90° with each other. Preferably the stakes are all driven to the grade fixed for the top of the monument, but this is not necessary. Strong, fine linen or silk thread is stretched between one pair of stakes and brought exactly over the point in the monument stake, and its position on the two side stakes is marked; and the same done with the other pair of side stakes. (It is well to protect the side stakes from accidental disturbance, as by driving four stakes around, and a few inches away from, each side stake.) The monument stake is then removed and the hole for the monument is dug. The monument is set in position and tested from time to time during backfilling by stretching the threads between the side stakes. If the side stakes are not at the grade of the monument top, they should, if possible, be higher, and the intersection of the strings be plumbed down. For this a small plumb-bob should be used, with a perfect point and suspended by a fine cord or thread. In plumbing down the intersection of the threads, care must be taken not to move them by the pressure of the plumb-bob string. A safe way is to suspend the plumb-bob (from a tripod or iron bar driven obliquely into the ground) exactly over each thread (simultaneously or in succession), but not at their intersections, and sight down with plumb-bob string and thread in line, to which line projected onto the monument the indicated point on the monument head should be brought. This method is applicable also when the threads are so close to the monument top as to leave no room for the plumb-bob.

In many cities points used as monuments are cut into the flagstone or concrete sidewalk pavement. There is no certainty that the pavement will not move, however; concrete pavements especially are subject to motion due to temperature and moisture expansion, and flagstones may even be taken up and reset without the surveyor knowing or remembering this fact when he next uses the monument marks cut therein.

Bench marks, as already stated, can be located on monuments; but there are not often a sufficient number of the latter

to use them alone; and unless the head of the monument is slightly rounded or a very flat pyramid, some other structure is generally better. As in the case of triangulation points, it is generally desirable to have a number of precise bench marks, from which the levels for the others are run and to which they are checked. These precise bench-marks can well be special ones set for the purpose, while the ordinary ones, scattered at intervals of not more than 1000 to 2000 feet throughout the

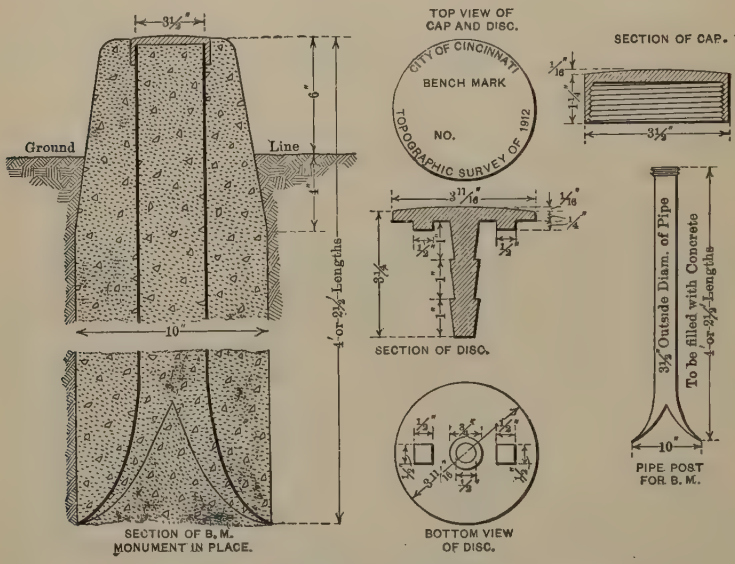


FIG. 70.—Standard Bench-mark, Cincinnati Topographic Survey.

city, are generally on the water tables or door sills of substantial buildings, tops of fire hydrants, well-set curb-stones, bolts driven into tree roots, etc.

In several cities precise bench-marks are made by cementing round-headed bolts into holes drilled vertically in the water tables or steps of buildings which are several years old and whose foundations are on rock or made as solid as local soil conditions permit. In connection with the topographical survey of Cincinnati, standard bench-marks were made by filling a hole 10 in.

in diameter and 2 ft. to $3\frac{1}{2}$ ft. deep with concrete, the concrete being carried 6 in. above the ground when possible and given a neat finish where exposed. In this concrete was set a $3\frac{1}{2}$ in. iron pipe, the bottom of which had been cut up about 6 in. and spread into a fish tail 10 in. across at the end. On the top of this pipe was screwed a cap of bronze which was $1\frac{1}{4}$ in. deep and whose top surface was crowned $\frac{1}{16}$ of an inch. The concrete surrounding the cap is brought up flush with its outer edge. The same city also used a bronze disc with a stem somewhat resembling a large thumb-tack, the disc being $3\frac{11}{16}$ in. across, the stem $3\frac{1}{4}$ in. deep and shaped like three superimposed inverted truncated cones, to give a firm grip in the concrete. The top surface was crowned $\frac{1}{16}$ of an inch. Other cities have used bronze rods an inch or more in diameter, rounded on top and set in concrete with the top just projecting above the concrete. Several of the kinds used in New York City are shown in the illustration. Some of these consist of copper bolts with slit and wedge at the bottom, which are set into holes drilled in steps, window-sills or other solid masonry. Others are set horizontally in walls with a flat horizontal surface projecting for the bench-mark. The ground type consists of a mass of concrete 3 ft. square and $4\frac{1}{2}$ ft. deep, in which is set a rein-

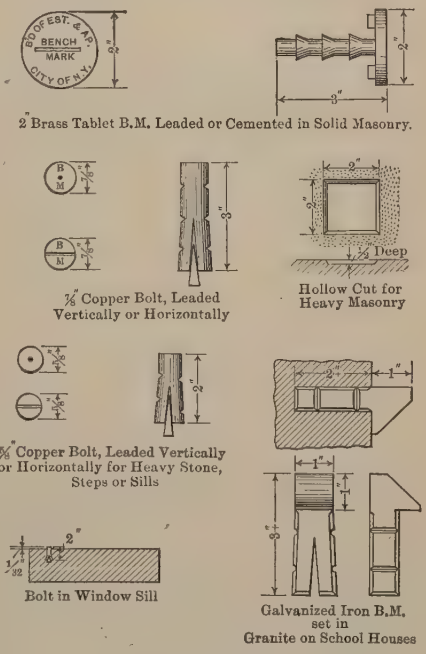


FIG. 71.—Standard New York Bench-marks, Set-bolt Types.

forced concrete or granite monument 6 to 8 in. square on top, in the top of which is set a copper plug $\frac{3}{4}$ in. by 2 in., the plug

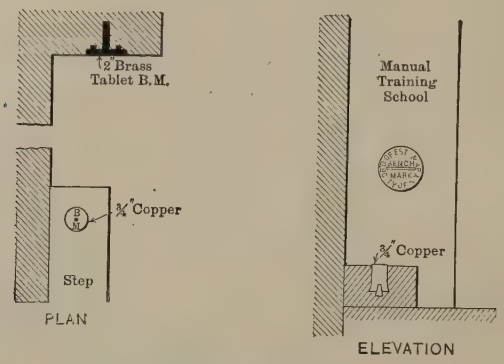


FIG. 72.—Tablet and Bolt Bench-marks.

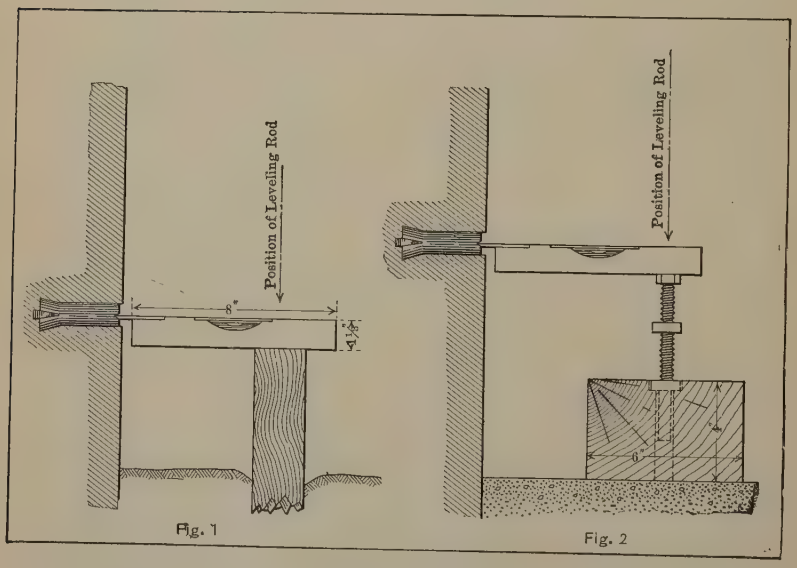


FIG. 73.—Methods Used for Taking Rod Readings on Bolts Set Horizontally into Masonry.

being protected by an iron box with cover, 13 in. square and 6 in. deep.

A horizontal bolt set in the vertical wall of a masonry building, bridge abutment, etc., is in common use in New York. The bolt carries a horizontal cut in its face (which is set $\frac{1}{4}$ in. back from the face of the wall). A hand level is used with a steel flange extending beyond one end in a plane tangent to the top. This flange is inserted in the horizontal cut in the plug, the other end of the hand level being supported by a stake driven to the exact elevation, or by a long screw turning in and out of a nut set in the top of a block of wood, which block rests on the ground. When the hand level is brought level by turning the screw or when resting on the stake, the rod is rested on the outer end of the level vial. These are not as convenient as those upon which the rod can be set directly, but are least liable to be tampered with or injured.

Art. 19. Coordinate Location

The ordinary method of laying out a street and defining its location is to state that it intersects some other street at a point so many feet from some other intersection, the two street lines at the intersection making a stated angle with each other. Similarly, a property is located by stating that its sides intersect the line of a certain street a given number of feet from some street intersection. Thus an error in one street intersection is liable to be continued indefinitely. Also, to find the relative position of any two points which were not included in the same survey requires either a special survey or a complicated calculation.

These and other objections are met by the method of coordinate location—defining the position of each point by giving its ordinate and abscissa from two axes. Given these axes permanently fixed with precision, any point in the city can be located with as great exactness as may be desired without reference to other points of doubtful exactness. The axes of coordinates are generally located outside of city limits or probable future limits, so that all coordinates will be plus; but in some cases pass through the city, the ordinates being designated as

N., S., E. or W. The primary axes in the first case need not be located on the ground, but the precise location is made of secondary axes, each an assumed distance from the primary axis and parallel thereto. Just as no bench-mark is set at zero datum, but an elevation is assumed so as to give no minus elevations in the city. In Cincinnati, both axes pass through a triangulation point near the center of the city, being the true meridian and the perpendicular to it.

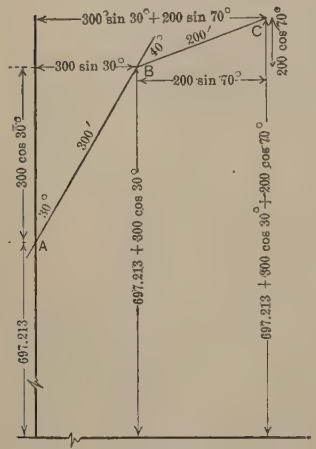


FIG. 74.—Illustration of Coordinate Location.

One set of axes, primary or secondary, at right angles to each other, are laid out very precisely on the ground and monumented by several monuments made as permanent as possible. Let it be assumed that a street line crosses one axis 697.213 ft. from the zero of coordinates (intersection of the axes), making an angle of 30° with such axis. A point 300 ft. out on this line has as its coordinates 697.213+300 cos 30°, and 300 sin 30°. If there is here an angle in the street, the forward tangent turning 40° to the right and therefore making an angle of 70° with the axis, the coordinates of a point 200 ft. out on this would be

$$697.213+300 \cos 30^\circ+200 \cos 70^\circ$$

and

$$300 \sin 30^\circ+200 \sin 70^\circ.$$

The distance of this point from the intersection of the axes in a straight line would be the square root of the sum of the squares of its coordinates. In general, the distance between any two points is the square root of the sums of the squares of the difference of their ordinates and the difference of their abscissas;

and the angle that the line connecting them makes with either axis is found by dividing one of these differences by the other, the quotient being the sine or cosine of such angle, as the case may be.

Perhaps the greatest advantage of this method is that the location of any point in the city can be described exactly by giving its two coordinates. And to locate any point whose coordinates are known it is necessary only to know the coordinates of any other point (preferably on the same street, for convenience) and the angle which a line passing through this point makes with the axis. Or, if certainty and exactnesss are very important, a line can be run to the point from the nearest monument on the monumented axis.

One of the monumented axes is generally made to lie in a long, straight street, for convenience in laying out and use. If there is no such street, a railroad tangent or a line through a park may be used, or a line connecting two summits, one of which is visible from most points on the axis. The aim is to have several monuments on the line, from any one of which at least one other can be seen.

Art. 20. Underground Records and Plans

Every city and town should have and keep up to date a map or maps showing the exact location of every structure placed below ground in the streets. This reduces cost of finding such structures for repairs, house connections, extensions, etc., and saves the street pavement from unnecessary tearing up. It also makes it possible to plan the exact location and depth of new sewers and other pipes and underground structures, so that existing structures shall not interfere with placing them. If begun in time, such records cost nothing but the trouble of making a few measurements to each structure before it is covered up, and recording the same. Every sewer, water pipe, wire conduit, gas pipe, and the appurtenances on these, should be located before the excavation in which they are laid is filled in. If put in by the city, the city engineer should include this among

his duties. If they are set by private parties, these should be required by law to file with the city engineer a map showing the location of each as soon as it is finished.

Information Desired. Sewers are generally laid straight between manholes, in which cases the location of the latter is sufficient to locate the sewer. But the vertical location is desirable also, so the depth of each sewer at each manhole should be recorded. There should also be recorded the location of each branch in the sewer for house or basin connection; generally done by giving the distance from the center of the nearest manhole. The line and grade of each connection from sewer to building line or to storm water inlet should be measured and recorded when these are built.

Water and gas mains should be laid parallel to the curb, but many times are not. Their location as to line and elevation should be determined at each change in grade or deviation from a straight line; and each valve, special casting, drip or other special feature should be located.

Wire conduits must generally run as true as sewers in line and grade between manholes, and need be located at manholes only. But cables buried without conduits may be carried anywhere, and should be located exactly with sketches of special locations when carried around obstructions.

Do not rely on any one's memory for a day. He may forget to make the memorandum " tomorrow," memories fail and men die. The location of every structure should be recorded in full before it is covered up.

Records of elevations of underground structures should be referred to the city datum and not be merely distances from the street surface, which may be changed later.

Recording Data. The original notes should be preserved, and the date of taking them recorded on them; but the data should be plotted on maps for convenience of reference. These must be at a scale sufficiently large to permit the showing of each structure to scale in its correct location. In Brooklyn the scale of 20 ft. to the inch is used; in Cincinnati, 40 ft. The former

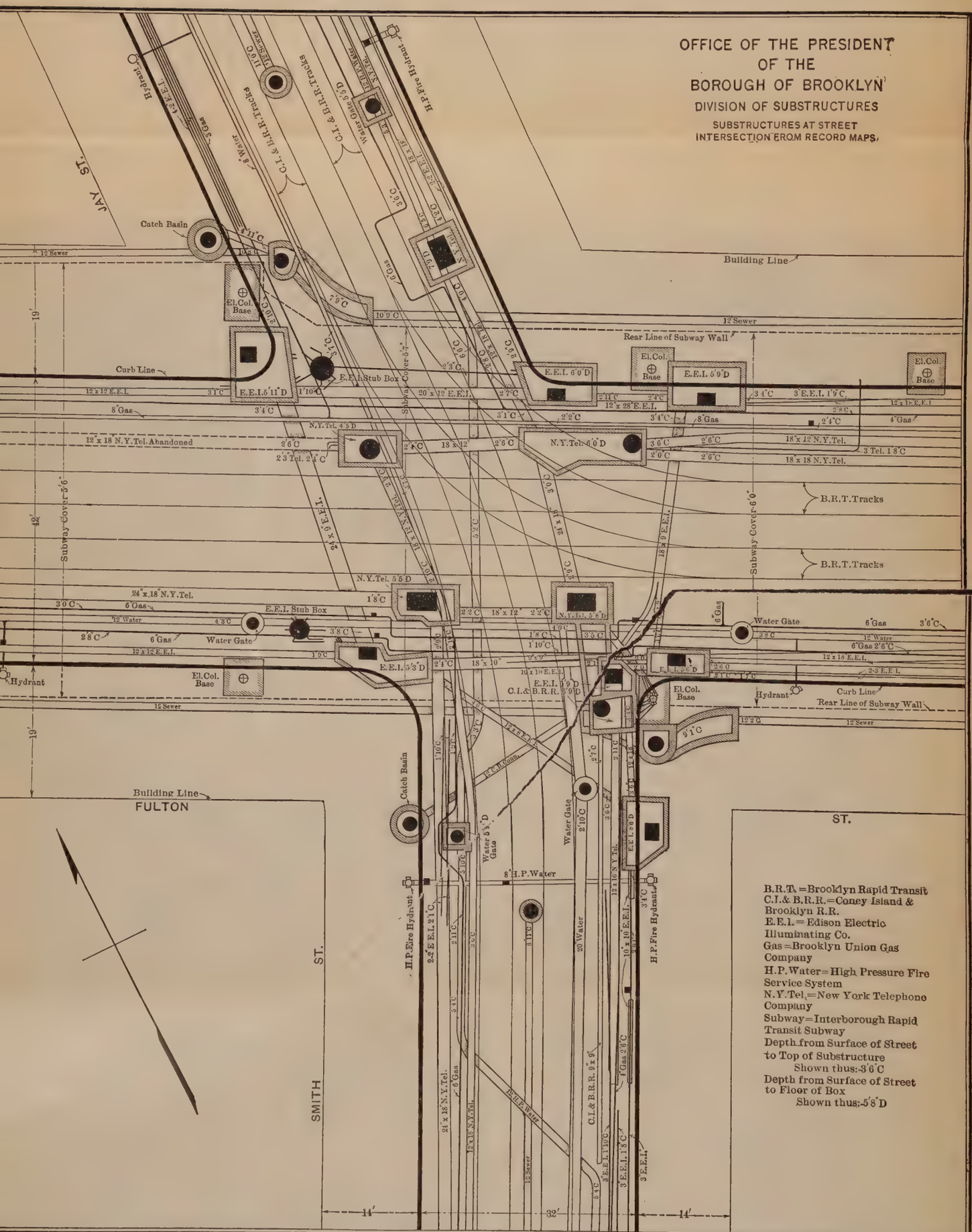


FIG. 75.—Map of Underground Structures, Brooklyn, N. Y. Prepared from Special Underground Survey.

To face page 246.

would seem to be none too large where the structures are numerous, but the latter will suffice where there are only three or four at an intersection. It is of course necessary to have a number of sheets rather than endeavor to place the entire city on one map. In Philadelphia a series of sheets is given to each street, which involves duplicating street intersections. In Brooklyn the city was divided into twenty sections, averaging 60 miles of street to a section, and these subdivided into areas which could be plotted at the standard scale on a standard sheet 32×42 in. (in Cincinnati the standard sheet is 23×32 in.) the whole of each street intersection appearing on one sheet and one only. To make this subdivision, a tracing cloth template is made representing the shape and size of the record maps, but to the scale of the city map used for this purpose. Using this, a lay-out for the record map subdivision is drawn on the city map, and the divisions numbered consecutively. Each record map is then filed by section and number, and by referring to the city map the number of record map containing any particular point in the city can be found. Where the streets are irregular in line or interval, it is generally impossible to completely fill each sheet without splitting street intersections or duplicating areas. The former is undesirable; the latter may have its advantages but generally is not worth the trouble.

As these sheets must be drawn to scale and embrace the whole city, they must have as their basis a survey of the city which gives the location of curb lines, building lines, hydrants, telephone and other poles, manhole covers and every object on the surface of the streets that will in any way serve as a guide in determining the location of substructures. These are plotted on the record sheets, generally in black ink. Sheets containing these surface features should be prepared as soon as a section or a street therein is accepted by the city; and afterward every subsurface structure plotted thereon as soon as completed. In addition to the lines, the distances between curbs are noted on the sheets, the elevations of curb corners, and of the substructures as they are plotted.

Subsurface structures are plotted, with their widths drawn to scale, and are given distinctive colors, as blue for water pipes, red for wire conduits, green for gas mains; lines being dotted where one structure passes under another, and elevations and distances being entered in the color of the structure to which it refers. On the Brooklyn sheets a number followed by " c " indicates that amount of " cover," or depth below street surface. Information which cannot be shown in the above manner can be stated in the blank spaces left between streets. It avoids confusion if distances are given in feet and tenths; diameters in inches; for wire conduits, the number of ducts.

In Moline, Ill., record maps show, in addition to underground structures, the official house numbers, service shut-off valves, etc. A number is given to each shut-off valve and to each valve on water mains. It is well also to number fire hydrants, sewer manholes, storm water inlets and other appurtenances, as this facilitates both keeping a record of how many there are of each and referring to them. Some systematic assignment of numbers according to location is recommended.

In order to keep the records up to date, there should be some system by which the official in charge is informed of the exact time when any underground work is to be done, so that a representative may be on hand to locate it. Every excavation in the streets should be visited, as any of these *may* furnish data as to underground structures not previously located. A level and rod, and tape are generally needed, and the structure located by distance from curb transversely of the street, and from curb line of intersecting street measured along the street excavated; also by elevation, obtained by the level from the nearest bench-mark.

Subsurface Surveying. In beginning such a set of records where none previously exist, the surface survey is made by traverse, as previously described, and the record sheets plotted. (In locating surface structures in busy streets, where the transit line is constantly crossed by pedestrians, this line may be chalked on the sidewalk between transit points (as by stretching and

" snapping " a chalked cord 100 ft. long) and offsets taken from this to building line, poles, manholes, etc.)

After the surface features are located, each manhole, valve box and other opening giving access below the surface should be investigated. A rod and tape are generally necessary, and three men, one to keep notes. For rod, Brooklyn uses a 16-ft. pole (because of deep sewer manholes) hinged at the middle, a piece of slotted steel on one half at the joint and a thumb nut on the other providing for fastening the two halves into a rigid pole. Graduation into feet and tenths are burnt into the rod, as hard usage and flowing sewage quickly remove painted figures. The rod ends at the bottom in a piece of iron 6 in. long to enable silt in the bottom of the manhole or sewer to be penetrated. Also a piece of iron fastened near the lower end projects 12 in. at right angles to the rod. This projecting iron is allowed to rest in the invert of any sewer which enters a manhole above the bottom, and the rod is then raised until the iron strikes the top of this sewer, the rod reading at the top of the manhole being taken in each position and the difference of readings giving the diameter of the sewer. At each manhole there should be ascertained the depth from top of cover to bottom invert, dimension at bottom, number of sewers entering, size of each and point of entering, and material of which each sewer is constructed. If any water or other pipes pass through the manhole, the location and size of these should be noted. An investigation of valve boxes will generally give size and depth of main as well as of valve.

A survey of the kind just described made in Cincinnati cost about $60,000 for 500 miles of street, of which the cost per mile for field work was $74, and for plotting the records, $46.

Subterranean Street Planning. As much care should be taken in locating structures under the street as on its surface, and the location of each should be carefully planned beforehand. A public service corporation should not be given a permit to place a pipe or other structure wherever it pleases in a street, but should be told where it can be placed. The city should also be able to tell the applicant just where every other structure in the

street is, so that he can plan his work accordingly. In making such location, common sense should be used—steam pipes kept away from refrigerating mains, deep sewers not located close to large water mains, etc. The information so given to the contractor or corporation intending to open a street may save him considerable expense, and a charge for it is justifiable. Philadelphia charges a minimum of $5 if the information is on hand and $10 if field work is required, the rate for less than 2500 ft. being 5 cents and 8 cents per foot without and with field work, respectively, and 3 cents per foot for all in excess of that length. The most logical plan would seem to be to combine this service with the giving of permits for street opening, and have the charge for information include the permit; the income from this to go toward the cost of collecting and plotting underground records, and planning the location of pipes, ducts, etc.

In subterranean street planning, the future should be allowed for as far as it can be foreseen, and the street area economized. All structures occupying a street longitudinally should be laid parallel to the street line. These may include sewers, water and gas pipes, wire conduits, steam and refrigerating pipes, and occasionally traffic subways. It must be remembered that all of these which occupy intersecting streets must pass each other at different levels at the intersections; and they should therefore occupy different levels throughout, as a general thing.

Sewers are generally deeper than any other structure, and are usually placed in the middle of the street. Water mains, because of the possibility of freezing, are generally buried from 4 to 7 ft. in northern climates and are frequently placed on the north and east sides of the streets, these being the warmest. Wire conduits are most often placed just below the pavement, and gas pipes intermediate between these and the water mains. As water mains are connected by relatively large pipe to fire hydrants along one side of the street, it is most economical to lay them near the curb.

We therefore have, as a general layout, water pipes say 4 or 5 ft. from one curb and 4 to 6 ft. deep; sewers in the street

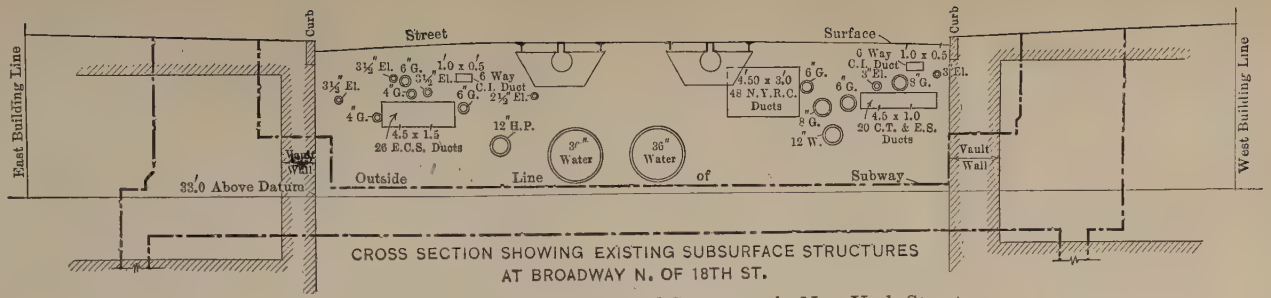


FIG. 76.—Congestion of Underground Structures in New York Street.

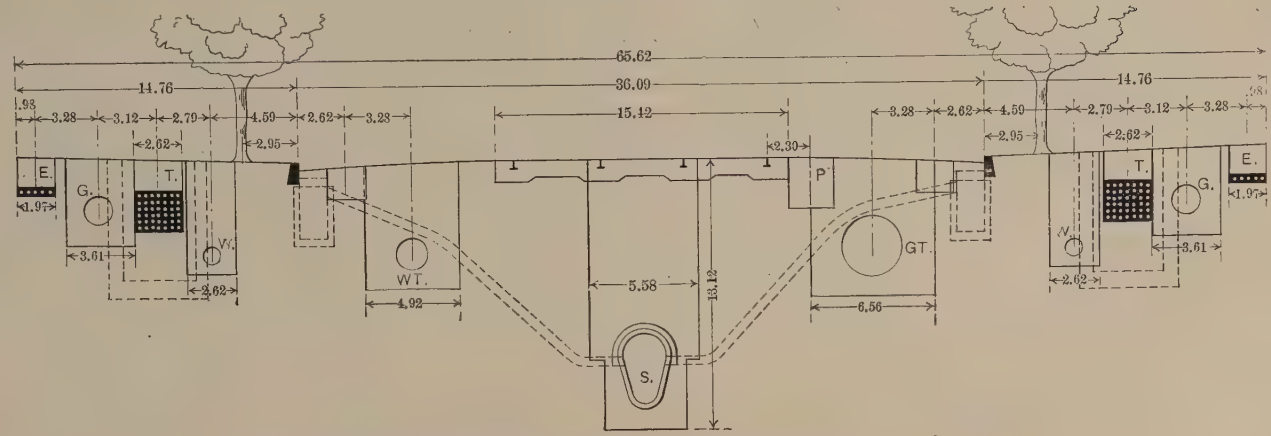


FIG. 77.—Allotment of Subsurface Area to Various Utilities, Hamburg, Germany.

center, 8 ft. or more deep; gas mains 3 ft. deep and wire conduits 2 ft. deep, the location of the last two being determined by local considerations. The sewers and conduits must generally be laid to a uniform grade between manholes, the gas pipes to grades which may be broken between and at drips. It must be remembered, also, that provision must be made for connections from each of these to buildings, storm water inlets, fire hydrants, lamp posts, etc., such connections passing under or over intermediate structures, and those from the sewer having a continuous rise.

The above suggestion of locations is merely to give an idea of the nature of the problem. In some cases one or more of the lines may be run through alleys or under sidewalks; there may be a line of sewer or water or gas mains on each side of a wide street, or other variations of the general problem.

It is a good plan to draw a location on the record sheet in pencil when it is assigned, and ink it in when the structure has been laid and measured up.

One of the accompanying illustrations shows the positions of the subsurface structures in Broadway, New York, after being rearranged to provide for the construction of the subway below. Most of these positions were determined by the original haphazard laying. The other illustration shows the locations allotted in a 20-meter street of Hamburg, Germany; *E* being electric light; *G*, gas; *GT*, trunk gas main; *P*, street railway cable; *S*, sewer; *T*, telephone cable conduit; *W*, water main; *WT*, trunk water main. Catch-basins and conduit manholes are shown by dotted lines.

Art. 21. Office Records and Methods

Note books are the original records of all field work of the engineer's office, and as such are of value both for reference in the office and for possible use as exhibits in law suits. They should therefore be kept safely in a fire-proof safe or vault; the notes should be entered neatly in a durable way; and reference to them should be facilitated.

The books should be kept either lying on their sides, or standing vertically and snugly packed to prevent warping of covers, but still permitting removal without force. Each book should have a number or letter, or both, which should be inked on the back, on the front cover, and on the front page. (The back is apt to break off in time, and sometimes the cover.)

Notes should be entered in hard pencil. Soft pencil marks smudge, and ink runs if the book is wet by rain or otherwise; but hard pencil marks can be read if a book falls into water and is dried.

Make the notes complete on the spot. Do not rely on entering additional notes (which some member of the party has taken on a scrap of paper) tomorrow—do it at once. Sketches should be used freely in explaining locations of bench-marks or other matters. In every case give date, names of men in party, exact location where work was done, and purpose of the survey.

To facilitate finding notes, each note book should have in the front (or back) a table of contents. It is better to classify notes, having only curb grade notes in one book, running street lines in another, etc. In addition, there should be a card catalogue of surveys made, giving book and page on which each is to be found. These are generally classified by streets (not by owner—the property may change hands), the street names being arranged in alphabetical order. Either there may be separate sets of cards for profile levels, street line location, subsurface surveys, etc., the cards in each arranged by streets; or all the cards may be combined in one classification by streets, but different colored cards be used for different classes of surveys—one color for sewer work, another for paving work, etc. The latter is probably better for a small office where there are few cards. One card would hold up to six to ten references relative to its particular class of work on the street to which it refers.

Profiles are generally kept in rolls, unless they are for single blocks or other short distances,when they may better be laid flat in a drawer. Or long ones may be folded in accordeon folds, the creases being reinforced by linen pasted on the back;

in which form they may be laid flat in drawers or bound as a book between covers. The rolled or folded profiles should be numbered and indexed, as described for note books.

Maps are best kept flat, for if rolled up they take up much more room, and when they become old are apt to break and tear when flattened out for use. Some of them, however, would require an almost prohibitive size of drawer; and such may have a stick fastened on one end, into which two small screw-eyes are fastened, by which the map is suspended by slipping the eyes over hooks properly spaced. Or the stick may extend a few inches beyond the map at each end, which extensions rest on supports or in hooks screwed into the ceiling. Maps so suspended should be protected from dust, either by keeping them in a dust-proof room or by fastening a sheet of common paper over the front and back by means of paper clips along the edges.

Some offices have two or three standard sizes of maps, with drawers to fit each size; others merely set a limit of size, and make each drawer large enough to receive all sizes. Each map should have a number inked on one of the lower corners by which it can be identified; and a list of maps should be kept, conveniently classified, giving number of map and drawer it is in.

In general, maps more than 2 ft. in either direction should be mounted. And any important map should be mounted, as it is then less liable to crack as it grows old. The title of the map should state definitely what it contains, the scale, and who drew it. It would be well also to give the numbers of the note books from which the map was plotted, although this is not often done.

The scale of a map should be adapted to its purpose. Where this is merely to show the street layout, and the area is large, 200 ft. to 1 in. is a common scale. If the locations and sizes of houses and property lines are shown, 50 ft. to the inch is a better scale; while if the locations of pipes and other underground structures are to be shown 20 ft. to the inch is about right, or even less.

Every city engineer's office should have a map of the entire city and immediate surroundings (especially those which may

be annexed), drawn to a scale of about 200 ft. to the inch (or 100 if the city is small), showing streets, streams and other features of the general city plan. It is better not to complicate this by putting on it sewer lines, water mains, gas mains, etc., but to have separate maps for these.

In addition to these large maps, which will usually be hung on the wall, it is desirable to have small maps on a larger scale showing such details as location of fire hydrants, valves, storm-water inlets, house connections and other surface features; also maps of underground structures as described in Article 20. These should be bound, preferably in loose-leaf binders. It is well to have a tracing of the city map for preparing these large-scale maps, this tracing giving only the street lines, streams, etc. Then black-and-white prints from this can be used for drawing the other details; or blue prints on which red ink is used for drawing.

Plans for constructions of any kind are commonly made on a standard size of sheet. Those for any particular work can then be bound together and used more conveniently than if of various sizes. Each should state in the title the general piece of work to which it applies, the exact feature given on this sheet, the scale, by whom drawn and by whom approved. It is well to give each a class number or letter and an individual number. The class may be either the special piece of work (such as some large contract), or the class of work (sewer, water works, etc.). A convenient method is to use thousands places for class and the three right hand figures for individual numbers. Ex. 7,004 indicates map No. 4 in class 7. A number of offices reserve only the two right hand figures for individual numbers—704 instead of 7,004, but the comma serves to separate class from individual number. Or this can be done by a dash, thus 7-04.

Field maps and plans are desirable, but full size plans or blue prints are awkward to use in the field or on the work. Several cities make photographs of maps, plans, profiles, etc., of a standard size to be carried in a loose-leaf cover. If well

made, the smaller details can be read with a reading glass (which every engineer carries), while the larger one can be seen without the glass. Others draw special section maps, plans, etc., on a standard size of sheet (say 4 by $6\frac{1}{2}$) of tracing paper, and bind blue prints of these in loose-leaf holders. For instance, the entire city map, on a scale of 200 ft. or 300 ft. to the inch, may be drawn on a number of such sheets, giving lengths of blocks, widths of streets, elevations of curb corners, etc.

Filing and Indexing. An excellent system of filing and indexing, adopted a few years ago by the engineering department of Brookline, Mass., is as follows:

Everything is indexed under the name of the nearest street, and also cross-indexed under every other street referred to. Plans, notes, and documents are indexed separately.

Plans of a standard size are used when feasible and filed in shallow drawers which are numbered, the plans being numbered consecutively. Not more than 50 plans are filed in one drawer. When large plans cannot be avoided they are rolled and filed in deep pigeonholes.

For indexing, white cards are used, 3 by 5 in., with tabs to designate different classes of works. Buff-colored cards are used for guides and blue for sub-guides. The tabs provide for 12 classifications. For the plan and note index the classifications are: map; street; sewer; drain; park; building; bridge; land plan; water; miscellaneous.

On plan index cards the street name is written across the top; below at the left is a space for the filing numbers; at the right of these, room for description of the plan; at the bottom are given date, scale, engineer and material. Only one reference is put on each card. A drawer book is kept, with two pages for each drawer. Each page is headed with the drawer number, and contains two narrow and one wide column. The left hand column contains the numbers 1 to 50; the next column the accession number of each plan; and opposite these, in the third column, brief descriptions of the plans. An accession book is kept which gives full information relating to each plan, enabling

it to be located if the index card is lost or misplaced; the information given being full title, scale, date, size, and material of the plan under its individual or accession number; initials of the assistant who made and plotted the survey, the purpose for which it was made, and where and under what street it was filed.

Notes are indexed under subjects in addition to the tab classification. About 20 subjects are used, such as calculations, estimates, levels, profiles. The classification is written in the upper left hand corner of the card, the street name in the right hand corner. Below are vertical columns for date, book, page, and a brief description. Several references relating to the same subject and street may be put on one card.

The loose-leaf system has been adopted for street line and grade work, and for sewer construction. These loose leaves are filed in the same manner as cards, under the proper street name, and do not need to be indexed.

All correspondence, reports, estimates, bids, descriptions, specifications, etc., are indexed under the name of the street referred to; in addition, correspondence is filed under the name of the person writing or written to. Tab cards are used for classifying as above, and further classified by sub-guides labeled street; sewer; drain; park; water; bridge; miscellaneous. If the document to be filed is a description of a street location, it is indexed on a "description" tab card, and placed in the index behind the sub-guide marked "street." The street name is placed at the top of the card, the date in the left hand column, next to this a description of the document, and at the right hand end the folder and document number. Documents are filed by the vertical system, in legal size folders numbered consecutively, no more than 50 sheets to a folder. Each paper is stamped with the number of the folder as well as an individual number.

Photography. A number of cities use photography as a regular branch of the work of the engineer's office. Portland, Ore., for instance, maintains a bureau of photography which

makes photographic records of all public construction and of features of any kind which it is thought may be valuable as evidence in future law suits. The equipment consists of a blue print machine with a 42 in. glass cylinder, using 44 in. mercury vapor tubes; operated by a 2-h.p. motor at a cost of 7 cents per hour. Cost $750. A rectigraph which makes paper positives of any size up to 12 by 16 in., and plates of any size up to 11 by 14 in. Capacity, 350 ft. roll of $12\frac{1}{4}$ in. paper. Cost $535.

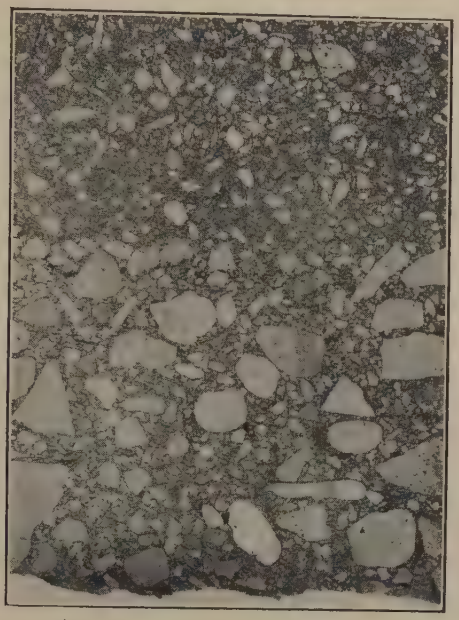
FIG. 78.—Blueprinting and Record Making Room, Photography Bureau, Portland.

A camera with Empire State view box, 5 by 7, with Goery Dagor lens, F 6.8 and wide angle lens F. 18. Cost $115.50. Dark room equipment, including enlarging apparatus. By the rectigraph reduced or original-size copies of maps, plans, deeds, letters, and records are made directly on sensitized paper; the machine containing developing and fixing tanks. This produces copies at a cost of 6 cents a square foot. The department also keeps photographic records of all bituminous pavements laid; a piece the full depth of the pavement being chopped out and

BUREAU OF STANDARDS

Contractor - Giebisch & Joplin Date sampled: 12-9-1915

Contract - E Stark, Brooke St. to E. 70th St.
Length in ft. 2420 Date of contract 9-3-1915
Location of sample:- Brooke St. 100 feet south of south curb line of Stark St. to 8 ft. from curb.
Asphaltic concrete on Bituminous Base.



SAMPLE OF WEARING SURFACE

A.C. -	11.45%	Sp. Gr. of finished top - 2.19
½	6.10	" " " aggregate on 10 ..... 2.72
¼	29.20	" " " " passing 10..... 2.66
10	20.35	% voids - 3.9 in finished pavement
40	25.00	% voids in aggregate - 27.55
200	7.90	
	100.00%	

SAMPLE OF BITUMINOUS BASE

A.C.	6.50%	Sp.Gr. of finished base..... 2.42
2	6.40	" " aggregate on 10 2.75
1	28.90	" " " passing 10 2.67
½	31.75	% voids - 1.6 in finished pavement
10	22.05	% voids in aggregate 16.44
200	4.40	
	100.00%	

Sp.Gr. of entire pavement as shown in photograph..... 2.31
% voids in total aggregate of same.....20.14

FIG. 79.—Portland, Oregon, Pavement Record.
One-half actual size of page.

sawed to a vertical section by a wire revolved like a band saw, wet emery being fed to the wire; the surface so formed being photographed full size. This photograph, an analysis of the ingredients and other information are then filed on a page of a loose-leaf record book.

CHAPTER VI

STREET LIGHTS, SIGNS AND NUMBERS

ART. 22. STREET LIGHTING

THE primary purpose of street lighting is to so illuminate the surface of roadway and sidewalk and the objects for 5 or 6 ft. above it that pedestrians and drivers of vehicles can travel safely. Of almost equal importance is the prevention of assaults or other illegal acts on the streets, the entering of houses by burglars, etc. A secondary purpose is to lend attractiveness to the street. In a business district and around public buildings it is desirable that the buildings themselves be illuminated; but in a residence section this is objectionable if the light be at all intense, because of the annoyance of light shining into bedroom windows.

If light strikes the buildings, it is reflected back into the street to an extent depending upon the color and smoothness of surface of the buildings and their nearness to the street. A given amount of light will furnish more illumination in a street lined with houses close to the sidewalk than in one where the houses are widely separated and set back from the street.

Trees, on the other hand, interfere with the illumination of a street unless the branches are all higher than the lamp; so that lights in the line of the roadway fail to illuminate the sidewalk and if over the sidewalk they do not illuminate the roadway; while if in the line of the trees they do not illuminate either, except directly opposite the lamp.

Illumination. The intensity of illumination from a given lamp is inversely as the square of the distance from it; also as the cosine of the angle of incidence (the angle the rays make with the normal to the surface). It is therefore impossible to secure

absolutely uniform illumination over the entire area of a street. The aim generally is to insure that the illumination will at no point be less than a given minimum, and secure as nearly uniform illumination as possible. Modern refractors greatly aid in this.

It is apparent that the illumination at a given distance from a lamp depends upon the brilliancy or candle power of the rays directed toward that point, its distance from the light, and the height of the light above the street. Different kinds of lamps differ in the relative intensity of light cast at different angles with the horizontal, and this can also be controlled to some extent by the use of reflectors and refractors. The most uniform illumination is obtained from a lamp which gives the maximum intensity of light a few degrees below the horizontal and its minimum vertically, with uniform variation between these. By placing the lamps near enough together so that their fields overlap sufficiently, the illumination may be made more uniform, even if the maximum rays are less nearly horizontal.

Amount of illumination actually given by a streeet lamp is measured by some form of illuminometer. Accurate measurements require laboratory methods. Where accurate results are not necessary, some form of reading photometer may be used. This consists of a box into which the observer looks through an aperture, while the light from the lamp enters through another larger opening and shines upon a card containing letters or characters of varying boldness. The observer walks toward the lamp until he is able to read the small characters and measures the distance to the lamp. This is compared with the distance from a standard lamp of say 16 candle power at which the same characters can be read, on the principle that illumination varies inversely as the squares of the distances. If, for instance, certain characters can be read at 4 ft. from a 16 candle power lamp, and if the same characters can just be read at 50 ft. from the street lamp, the candle power of this lamp in that direction is $\left(\frac{50}{4}\right)^2 \times 16 = 2500$. To reduce the illumination

to that on a horizontal plane, multiply that in the photometer by the height of the lamp above the photometer and divide by the distance between the two.

Such a photometer can be made of a box say 16 in. long and 8 in. square, provided with an orifice for the eye near one end of one side; opposite this, inside the box is fixed a card of characters such as opticians use for testing eyes; and a tube about 5 or 6 in. in diameter set in the same side of the box as the eyepiece and making an angle of 45° with it and directed toward the card of characters. The box should be light proof at all joints and it and the tube painted a dull black inside. More elaborate and expensive illuminometers may be purchased which will be more accurate, also more difficult to operate.

Comparisons of street lighting are best made in flux of light per unit of length or area of street. Up to two or three years ago watts per running foot was the unit used, and this is still possibly more common than the other, but is less reliable. Average foot-candles of illumination on the street surface would be more accurate, but as this varies over the entire surface its calculation would be too laborious. (A foot-candle is the normal illumination produced by one candle power at a distance of 1 ft.)

Mean spherical candle power is the average candle power given by a lamp in all directions. The flux of light emitted, expressed in lumens, is equal to 4π times the mean spherical candle power; and that in any given zone equals the mean candle power in that zone multiplied by the corresponding solid angle. Since the unqualified lumen is the highest value obtainable, it is less likely to be used by promoters to deceive than candle power has been.

Amount of Illumination Required. Street lighting in the suburbs may consist only of beacon lighting, in which the lights are used chiefly to indicate the course of the road, only a relatively small area of street receiving any appreciable illumination.

When the lights are placed at shorter intervals we have uneven illumination or spot lighting, in which there are still areas between lamps which appear to have little or no illumina-

tion. There are some advantages claimed for this as offsetting the disadvantages and making it preferable to uniform low intensity lighting. With uneven illumination, large objects, such as vehicles, when in the dark spots are seen in silhouette as dark outlines against the illuminated street surface beyond and, it is claimed, can thus be seen at a much greater distance than if the same total amount of light were evenly distributed. (There are, however, other purposes of illumination besides locating vehicles, which are not so well served by uneven lighting.) And since high-power units widely spaced cost less per mile of street than low-power units at correspondingly narrower intervals, the uneven lighting is the cheaper. But it does not light the sidewalks effectively; nor the streets either, where there is dense foliage or the streets are curved. Also, there should be a light at each street intersection, because here is the greatest danger of collision between vehicles and to pedestrians crossing the streets; and if the streets are close together this may render the wide spacing impracticable.

When the intensities of illumination of different parts of a street surface do not vary more than 10 or 15 to 1 it appears to ordinary observation to be quite evenly lighted. The appearance of the street is more pleasing than with spot lighting; and there can be no question that if the minimum is at least equivalent to moonlight, all objects can be seen more plainly than with uneven lighting. This minimum is stated by different authorities to be .02 foot-candles, .025, .028, etc. The first is probably the lowest which would justify calling a street illuminated throughout, and should be the minimum for residence streets. Very much more than this is considered necessary for business streets—from .25 to 1 foot-candle. Secondary business streets and main traffic streets should have not less than .1 foot-candle and in some cases have as high as .5.

The color and smoothness of a pavement have an effect on illumination which is not often considered. A dark street surface demands much more light for effective seeing than a light-colored one. The darkening of light macadam streets by oiling

them often makes very appreciable difference in the illumination. Asphalt pavements and oil-treated roads give a high degree of specular reflection; granite block and dirt absorb most of the light, but reflect a little diffusely. The color and smooth or rough surface of the buildings also have considerable effect.

In the most complete street lighting plans made for Milwaukee in 1915 the following illumination intensities were adopted:

Nature of Street	Foot-Candle Intensity
Alleys and outlying streets	0.01
Residence streets	0.03
Subsidiary traffic feeder or thoroughfare	0.06
Main traffic feeder or thoroughfare	0.12
Promenade and principal business street	0.50

Lamps. To prevent glare, high-intensity lamps should be enclosed in diffusing globes. To concentrate the illumination in one direction or otherwise alter the angles of light rays, reflectors and refractors are used. Each of these absorbs light, but more than compensates for this be reducing dazzling effect and equalizing illumination. Reflectors are recommended for lights up to 100 c.p. and spacing up to 150 ft.; and for 250 to 400 c.p. lamps for distances up to 250 ft. For greater distances, refractors give better results. The best refractor is that known as the Holophane prismatic refractor. These are made of transparent glass with prismatic refracting surfaces designed on the lens principle. There are two bowls, one fitting snugly inside the other, with the joints sealed to make an air-tight union. The inner bowl is girdled on its outer surface by horizontal prisms which refract the light from the source at an angle of 10° below the horizontal. The outer bowl has vertical diffusing prisms on its inner surface for the purpose of spreading the light rays transversely and making the refractor luminous over its entire surface. Reflectors and refractors are not generally used in the business district, where it is desirable to light the fronts of the buildings as well as the street surface.

Electricity is most commonly used for street lighting in this country; but a large number of gas lamps are in use, and a few

vapor lamps. Of electric lamps, the nitrogen-filled tungsten-filament incandescent are being used in the most modern installations; the old carbon arcs having practically gone out of

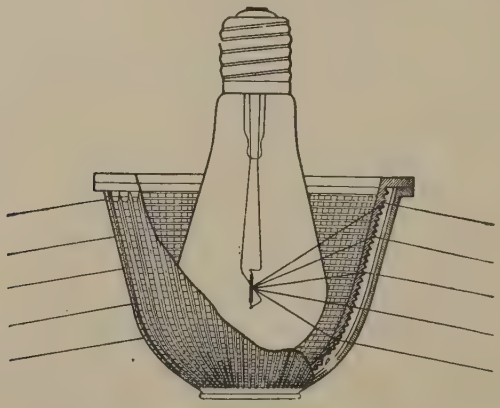


FIG. 80.—Principle of the Prismatic Refractor.

use except in old installations. For display illumination, flaming arcs are used, but are not as economical as tungsten. A 600 c.p. tungsten gives about twice as much illumination

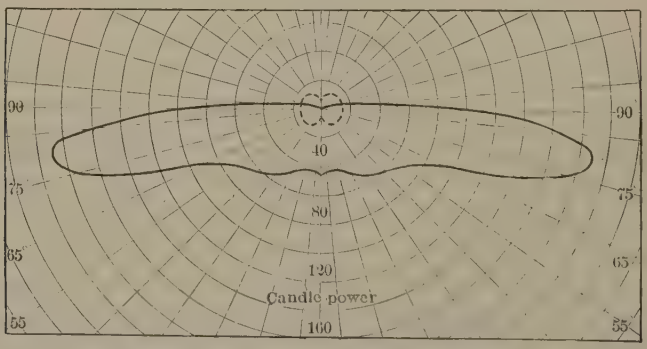


FIG. 81.—Distribution Curve of 100 Candle-power Lamp with Refractor.

as a 7.5 amp. carbon enclosed-arc lamp, with 40 per cent less energy consumed. They can be had of various sizes from 100 to 1000 c.p.

Open flame gas lamps are no longer installed for street lighting; but mantles, either erect or inverted, are now in general use. From 60 c.p. to 1000 c.p. gas lights are in use.

The initial cost of gas lamps is less than of electric, but the maintenance—lighting and extinguishing, replacing mantles, and in many cases the energy—is higher.

Vapor lamps are not used where gas or electricity are available. They are cheap to install, but expensive to maintain and are not practicable for high candlepowers.

Installations. For *business centers*, one of the brilliant lights on a high pole and spaced between 60 and 120 feet apart, on opposite sides of the street, is usually preferred. Reflecters are not generally used here, but part of the light is allowed to rise above the horizontal to illuminate the buildings, which are near the street and are (or should be) pleasing in appearance. Electric lights are almost always used, and in most cities the wires are buried under ground and the posts are more or less ornamental.

A five-light standard is used for such service by many cities, carrying four 60-watt side lamps and one 100-watt top lamp. Each 60-watt is enclosed in a 12-in. outer globe and the 100-watt in a 16-in. outer globe. Usually the top light burns all night, but the side lights are extinguished at the end of business or pleasure hours. A cheaper equipment consists of 40-watt side lamps and 60-watt top lamp, all in 12-in. globes.

Still greater illumination can be obtained by using one 400 c.p. Type C series lamp (" gas-filled "), which gives about 50 per cent more light than the five-light 100-watt and 60-watt standard. This light has become very popular during the past few years. It lacks one advantage of the multiple-light post—that $\frac{24}{31}$ of the latter need burn only half the night. To partially meet this, the single-light standards may be so arranged that alternate ones may be extinguished while the other half remain burning all night.

From figures obtained in 1915 from a large number of cities in all parts of the country, it was learned that for " white way " or intense lighting of the principal business streets, 33 per cent

used the five-light 100-watt and 60-watt standards; 16 per cent used the five-light 60 watt and 40 watt; 16 per cent used five 60 watt lamps to a standard; 7 per cent used five 100 watt lamps; 7 per cent used 500-watt tungstens; while others used single lights and 4-light standards of less brilliancy.

In this display lighting the lights are generally placed opposite buildings and not at street corners; because the merchants (who most often pay for it) wish the lights opposite their stores, the reflection from the buildings increases the amount of illumination and adds to the general appearance of the street, and a lamp at the curb intersection is apt to dazzle the eyes of a driver turning the corner. One or two lights to a standard are more efficient than clusters, and afford a more pleasing street perspective.

Ordinary business streets, and thoroughfares and residential streets in which the houses are not detached and are close to the street and there are no trees, should be treated as just described, although the lights may be less brilliant or less numerous or both. Here it may be desirable to place lights at street intersections if other treatment would not give sufficiently bright illumination to prevent accidents to rapidly moving vehicles whose paths cross or turn there.

For *residence streets*, electric, gas or vapor lamps may be used. The common practice a few years ago was to suspend an arc lamp at the center of each street intersection. Later, incandescents of 32 to 60 c.p. spaced 150 feet apart, more or less, on both sides of the street were used by many cities. The former was most economical, but if the blocks were more than 300 or 400 ft. long it gave almost no illumination in the middle of the block and a bright glare at the corners; the alternation being very trying to the eyes of drivers. (This is true of any lights over the center of the road, and side lights are preferable for this reason.)

The most uniform lighting for residence streets, with avoidance of glare, is obtained by low-power lights spaced 50 to 75 ft. apart; but the cost of standards and lamps makes this

plan expensive. Perhaps the most satisfactory is a mean between these—lamps of 60 to 100 candlepower spaced 150 to 200 ft. apart. Economy dictates that a lamp be placed at every corner, since it lights twice as great a length of street as one in the middle of a block. If the corner lights are more than 150 to 200 ft. apart, then an intermediate light or lights are desirable. There should be a light at each bend in the street, placed on the outer side of the curve.

Locating Lights. The danger from lack of illumination is greater in the roadway than on the sidewalk, and the lamps should therefore be placed on the gutter side of the shade trees. One argument in favor of placing sidewalk pavements next to the gutter, and the shade trees along the property line (about the only one, in the author's opinion) is that the trees do not interfere with the illumination of both roadway and sidewalk by the same lamps. A lamp buried in foliage is of little use, and where shade trees overhang the gutter, the lamps should be set below the lowest branches, or the branches all trimmed up higher than the lamps; or at least the branches near the lamp should be kept so trimmed that the light can shine up and down the roadway. A lamp 10 or 12 feet above the roadway with all branches trimmed a foot higher is, perhaps, the most satisfactory for maples and other low trees; but with elms there should be little difficulty in using lights even 15 ft. high without interference of branches, should the candlepower of the lamp make this desirable. A number of cities use mast arms for suspending the lamps several feet from the curb into the roadway, where foliage at the curb line interferes; but the appearance of these is not pleasing and the light glares in the eyes of drivers.

There is difference of opinion as to the relative advantages of placing lamps opposite, staggering them on both sides of the street, and placing them on one side of the street only. The opposite arrangement probably gives the most pleasing appearance; but more uniform lighting on narrow streets, especially with wide spacing, is obtained by staggering. But on curved

roadways where the illumination is faint, staggering is apt to mislead drivers as to the course of the roadway, and all lights should be on the same side of the street. On narrow residence streets, especially where mast arm suspension is employed, locating poles on one side of the roadway only is economical and effective. Where there is a central parking in a street, placing the lights on standards in this parking has been found very advantageous.

Height. Lamps of high candlepower should be at least 25 ft. above the street surface—the brighter the higher. Also the greater the percentage of light which is directed nearly vertically, the higher the lamp should be. High-power pendent lamps along the curb are usually 18 to 25 ft. high; but pole top lamps with diffusing globes are often placed as low as $14\frac{1}{2}$ ft.; while lamps of low candlepower at the curb are often only 10 to 15 ft. high.

In the Milwaukee plans, 15 ft. to center of globe was selected as a minimum height, used for residence streets, and others where trees prohibited a greater height. For suspended units, and post units on secondary business streets, $22\frac{1}{2}$ ft. was used. Thirty feet was selected for the principal business streets, and important thoroughfares where trees did not interfere. In a few public squares and large open spaces, 45-ft. posts were adopted.

An effort was made in these plans to secure uniform illumination by use of Holophane globe refractors and proper spacing. It was found, by studying the prototype curves, that unless the ratio of spacing distance to mounting height be 8 or less, this result could not be secured; and 8 was adopted as a standard, with 6 for certain streets of intense traffic and 12 for residence districts with light traffic. The ratio multiplied by the height of the lamp gives the distance between lamps for uniform illumination. Thus, using ratio 8, lamps 15 ft. high would be placed 120 ft. apart.

Lighting Survey. Before deciding upon a lighting program for a city, a survey should be made of conditions, and possi-

bilities canvassed. Street and traffic conditions at night throughout the city should be studied in order to determine the illumination requirements of each block. Kind of street pavement; character and number of buildings and nearness to street line; presence, nature and density of trees and height above the street of their lowest branches; alignment of streets, location of bends—all have their bearings upon the plan, as already described. Intensities of illumination required for each block are determined, and recorded as lumens per running foot of street. From this can be calculated the number of lamps required and power of each in lumens.

The kind of lamp adopted will depend upon local conditions and relative prices of electricity and gas; also the state of the development of lighting units at the time. A continual progress is being made in efficiency and effectiveness of electric lamps.

Current Distribution. In choosing a general lighting scheme for any city, the central station furnishing must be considered. If direct current lamps are adopted they should all have the same current consumption. With alternating current lamps, small compensators or transformers may be used to adapt them to any A. C. circuit.

Electric current may be distributed by either the series or multiple system, but the former is almost always used for street lighting. Either direct or alternating current may be used with either. Some types of arc lamps will operate on either direct or alternating current, others on direct only. Electrodes for alternating current arc lamps are somewhat more expensive than for direct. Transmission wires must be larger and more expensive the lower the voltage; and alternating current can be transmitted at high voltage and transformed to a lower at the lamp. Also, by use of rectifiers alternating current can be changed to direct, a rectifier being used for each group of lamps. There is loss in each of these changes, and regulators and rectifiers add to the cost of the outfit, and some maintain that these more than outweigh the transmission economy of alternating

current. This economy, however, varies with the length of the distribution system.

Lamp Standards and Installation. Lamp standards or posts should be an ornament by day, or at least not detract from the appearance of the street. They should be and appear substantial but not clumsy. The greatest number in use are of cast iron; but quite a number, especially of the one-light (upright) standards, are made of concrete, generally reinforced with steel rods and with a wrought iron pipe up the center to carry the wires. A number also are made of wrought iron or steel. Iron or steel ones must be kept painted, and for appearance's sake this should generally be done about once a year. The concrete of course are not painted; but they may occasionally need patching, as the surfaces, especially corners, are apt to be chipped off by wheel hubs or blows from hard substances.

FIG. 82.—Concrete Standard, Bronze Top.

The greatest danger, from the point of view of appearance, seems to be that the standards will be too heavy. A heavy column with massive branches at the top is not necessary to support one or even five hollow glass globes, and looks absurd doing so. We have never yet seen a cast iron or concrete lamp standard which looked too light, but have seen scores which were unsightly and inartistic because of their bulk.

The wires supplying current to electric lights are generally carried on posts (in this country), although it is becoming common to place them underground in conduits in business sections, in parks and even in the better class of residence streets; and in

all streets in the central parts of many cities. In the case of gas lamps, the supply pipes are of course placed underground.

Instead of placing the wires in a conduit, a steel-taped cable is often used and is found very satisfactory and lasts for years without deterioration from moisture or other cause, unless struck by pick or other heavy tool while excavating near it. This cable may be laid a few inches below the surface just back of the curb or under the gutter, and can be deflected around trees, catch basins or other obstructions without difficulty. The steel tape is about $\frac{1}{32}$ in. thick, and the jute serving about $\frac{3}{32}$ in. A single conductor cable will suffice for single-light posts, all burning on the same schedule; two-conductor cables if they burn on different schedules.

When the cable is laid, a loop is left at each post for the connection to the interior wiring of the post. This connection, for a five-light standard, is generally made through a 3-wire cut-out or fuse plug placed at an opening at the base of the post. In the case of iron posts, these should be well grounded to prevent shocks to persons touching the post. For a single-light series standard, connection is made through a cut-out or pothead, the latter serving to safely ground the cable. For wiring inside the standard, rubber-covered, double-braid solid copper wire is used, with insulation sufficient for the voltage used.

The standard should be bolted to the sidewalk, if this be of concrete or stone, by drilling holes under the bolt holes in the base, setting foundation bolts in these, head down, and filling the hole with lead, sulphur or grout. If there is no sidewalk under the standard, a base of concrete about 24 in. square and 30 in. deep should be built in place, the foundation bolts being set in the green concrete, their ends projecting through a template to insure their proper location. There is also built in this concrete base a conduit of iron pipe, a tile elbow or other opening for passing the cable up to the standard.

Street Lighting Contracts. Where lighting is done by a private company under contract with the city, the company supplies the current or gas, and generally the wires or mains through which

it is brought to the lamps; and keeps the lamps in order. The lamps and supports are sometimes supplied and owned by the company, but a better plan is to have at least the standards or posts owned by the city; for a change in contractor does not then mean the annoyance and expense of changing these fixtures. The contract should be for at least three to five years, and some cities make longer ones; for the company must make sufficient profit to reimbuse it for supplying and removing the installations, the central plant, etc., and the longer the period over which it can spread this, the lower it can afford to make its rates.

The contract for street lighting needs careful attention, for it is by no means a simple matter to prepare a satisfactory one. Rochester, N. Y., has for a number of years made a special study of the matter of street lighting, and has employed therein greater technical ability than most cities. Its present contract provides as follows:*

The company is to furnish lamps, lamp posts, wires and accessories and maintain and operate the same in any number required by the city, but not less than 4500. The company furnishes, repairs and paints lamp poles or posts, lamps and supports, and keeps the lamps clean and lighted; putting up and operating such additional lamps as may be required at any time by the city, within thirty days after an order to do so.

It is to keep all lamps lighted and in full operation continually every night, the lamps to be lighted one-half hour after sunset and kept lighted and in full operation until one-half hour before sunrise, or such other times as the proper city officials may require, the total number of hours per year to equal 4000. Outages of lights through no fault or negligence of the company are to be deducted from the city's payments at the rate of such payments; but if the company fails, refuses or neglects to light the lamps or keep them lighted, it pays as liquidated damages to the city double the amount which it would be entitled to receive for light during that time; and if this continues for two or more nights, it pays the city five times the amount it would be entitled to receive. If such failure to light the lamps continues so long as to require the city to provide other lights, the additional expenses of all such emergency lighting is charged to the company. Should any of the lamps fail to give a clear and steady light of the full intensity and power of the best and most approved lamp adapted for and using the

*This abstract is from *Municipal Journal.*

electric current or energy specified in this contract, when such lamp is in perfect order and equipped with clean globes, the company is to replace these lamps with others complying with the specifications. The company must employ a patrol to inspect and renew lamps, a sufficient number of patrolmen being employed so that each lamp shall be inspected at least twice a night; the city having the right to provide the necessary inspection and charge the cost to the company if the latter does not comply with this requirement.

The company also is to furnish and apply all switches, cut-outs and other apparatus so as to prevent fire or danger of any kind or which may be necessary for the proper operation of the lamps. It is to "use any and all devices and improvements, if approved in writing by the city engineer, the effect of which shall be to increase the relative amount of light produced and improve the kind, quality and power thereof during the life of this contract, for such additional lights as may be ordered during the life of the contract."

Provision is made that the company shall permit other companies to place their wires upon its poles, also to use the poles of other electric companies where they have suitable ones in the street in question, the object being to have only one line of poles in any one street where this is practicable. The compensation for removing surplus poles and for using poles of other companies shall be agreed upon by the several companies, or, if they are unable to agree as to compensation and conditions, this shall finally be decided by the commissioner of public works. The company also agrees to permit the city to use its poles for fire alarm telegraph or police patrol wires. At the expiration of the contract the city has the right to purchase poles used for carrying wires or supporting lamps, subject to the rights of other companies having wires on the poles, the price to be agreed upon between the company and the city, or, if this is impossible, to be determined by three arbitrators.

The company agrees to indemnify the city against loss from lawsuits of any kind, damage suits for injury to persons or property, for infringement of any patent rights, etc.

The company agrees to provide, equip and maintain underground conduits for its wires whenever and wherever the common council may direct, up to a total length of not to exceed 150 miles of single duct, although more may be laid with the consent of the company. The city engineer shall have the right to order the change of location of any pole, the expense of this to be paid by the city. The city has the right to at any time change lamps in any street or part of a street from the single arc system to the double arc system or from the double arc to the single, or to make any changes from one kind of lighting to another kind specified in the contract. The city may order any lamp or lamps discontinued and payment for the same shall

cease within twenty-four hours after receipt of such order. All additional lamps erected in streets having suitable conduits are to be connected with underground service, and any lamps already in service on overhead wires shall be changed to underground service where conduits exist or are ordered by the proper city officials, at the expense of the company; the lamps, of course, to be paid for thereafter as lamps on underground service.

The various kinds of lamps and service provided for in the contract were as follows:

Said city hereby agrees to pay for each and every lamp placed, actually lighted and in operation (the total at any one time to be not less than 4500), as specified herein as follows:

For a term of five years, commencing July 1st, 1912:

(*a*) For each arc lamp supplied from underground wires in the subway, located singly, 18.63 cents per night.

(*b*) For each arc lamp supplied from underground wires in the subway, located in pairs, 17.25 cents per night.

(*c*) For each arc lamp supplied from overhead wires, located singly, 15.875 cents per night.

(*d*) For each 60 candle power incandescent lamp supplied from overhead wires, 4.94 cents per night.

(*e*) For each 60 candle power incandescent lamp supplied from underground wires in the subway, 6.2 cents per night.

(The same form for 80, 100 and 200 candle power lights.).

(*l*) For each five-light ornamental post supplied with five 80 candle power lamps, where post is not furnished by the company, 17.4 cents per night.

(*m*) For each five-light ornamental post supplied with five 80 candle power lamps, where post is furnished by the company, 24.66 cents per night.

(*n*) For each luminous magnetite arc lamp operating on not less than 6.6 amperes, and requiring not less than 520 true watts energy at lamp terminals, located singly, 25 cents per night.

This contract contemplates the use of what is known as the enclosed arc lamp of the series alternating current system, operating on not less than $7\frac{1}{2}$ amperes of current, with 72 to 80 volts at the lamp terminal, requiring not less than 450 true watts energy at the arc. The contractor, however, may use in lieu thereof lamps of the constant potential direct current system, operating on not less than 5 amperes, with 70 to 80 volts at the arc, requiring not less than 360 true watts energy at the arc, operating on the 120 volt system; or luminous magnetite arc lamps of the series direct current, operating on not less than 4 amperes of current, with 72 to 80 volts at lamp terminals, requiring not less than 320 true watts energy at lamp terminals.

SPECIFICATIONS

The following types of arc lamps may be used:

Enclosed arc lamps of the series alternating current system, operating on not less than $7\frac{1}{2}$ amperes of current, with 72 to 80 volts at the lamp terminals, requiring not less than 450 true watts energy at the arc; enclosed arc lamps of the constant potential direct current system, operating on not less than 5 amperes with 70 to 80 volts at the arc, requiring not less than 360 true watts energy at the arc, operating on the 120 volt system; and luminous magnetite arc lamps of the series direct current system, operating on not less than 4 amperes of current, with 70 to 80 volts at lamp terminals, requiring not less than 320 true watts energy at lamp terminals.

Incandescent lamps to be the standard series or multiple Mazda tungsten street lamp, and may be operated from the constant potential system or on any of the regular series arc circuits. Brackets and reflectors must be provided of a pattern acceptable to the city engineer.

Globes. The globes, both enclosing and outer, shall be of the best and most approved form for the lamps to which they are attached.

Cleaning Lamps. All globes shall be cleaned as often as necessary to keep the lamps in condition to furnish the maximum amount of light.

Lamp Posts, Supports, Etc. All wooden poles erected and used to support lamps and wires shall be of such length, size, quality and shape, and shall be painted, set and guyed, and all cross-arms shall be of such kind and size, and be painted, as shall be directed by the city engineer.

In that portion of the city where conduits of the Rochester Railway & Light Company now exist, or may hereafter be extended, the city engineer may require the use of iron or concrete poles for the support of lamps. Said poles shall be of such form and dimensions, and shall conform in all respects to the requirements of the city engineer, and be thoroughly grounded.

All cranes and other devices for supporting lamps shall be of such form and dimensions as may be approved by the city engineer. No signs, advertisements, bills, defacements or unnecessary attachments of any kind or nature whatever shall be placed, put or attached to any of the poles, supports and cross-arms; and all necessary attachments shall be painted as often and of the color and style required by the city engineer. Any poles, supports, cross-arms, attachments, wires and lamps of said company shall be changed or removed by said company whenever the same shall become unsafe, or whenever for any other reason such removal or change is ordered by the city engineer.

Wires, Currents, Etc. All wires used by said company pursuant to this

contract shall be of the best quality of weather-proof insulated wire, and, when run on poles, be securely fastened in a first-class manner. Wires used in the electric conduits shall also be of the best quality of material and insulation adapted to the service. Said company shall make and file with the city engineer a report describing each circuit for furnishing street lights, including the size of wires used, kind of insulation, the length thereof, and the route of each circuit, the number of lamps and kind on each circuit, immediately upon the execution of this contract; and any construction or erection of a new circuit or circuits, or any changes made in the old circuits, in the number of lamps, wires and route of said circuits, shall be immediately reported to said engineer.

All circuits erected and used under this contract shall be tested by said company for grounds and escapes each and every day during the life of this contract, within one hour of the time of lighting said lamps.

Where electric lamps are suspended from iron poles and are supplied with current by cables in conduits, the maximum voltage on said wires so supplying such lamps shall not exceed 5000 volts, and all iron poles carrying over 250 volts shall be thoroughly bonded to the water or gas pipe system. Lamps on opposite sides of Main street operated on the series underground system shall not be in the same series. In other parts of the city where lamps are attached to or suspended from wooden poles the current supplied to the lamps shall not exceed a maximum of 6600 volts.

General. All lamp posts, poles, wires, conductors, lamps, globes, carbons, and each and every article, apparatus or device which may be necessary for electric lighting under this contract, shall be of the best quality of material and workmanship, and be furnished and maintained by said company at its own cost and expense. The lamps, wires, and all and every conductor must be thoroughly insulated in the best and most approved manner and placed in such locations and in such manner as to prevent them from being tampered with, or handled by, any unauthorized person or persons.

The city engineer or other proper officer shall have adequate facilities for testing the candle power of the lamps to be furnished and operated under this contract. Said city, through its proper officers, shall also have free access to the central station or stations of said company for the purpose of inspecting and making tests and measurements, and every facility shall be given its proper officers or agents therefor.

Said company shall also furnish any instruments in addition to those owned by the city, and such assistance as may be required by the city engineer or other proper officer in charge of lamps, to ascertain the candle power of any of the lamps or the energy supplied to the lamps.

The cost of street lights, or the prices paid to private companies for the same, differ widely in different cities under different circumstances. The operating expenses connected with generating gas or electric current will vary with the local cost of coal or hydro-electric energy. Maintenance of the outside plant, which includes the materials, supplies and labor for keeping up the lamps and their supports, poles and wires, or pipes, office expenses and all salaraies and wages will be more uniform. Investment charges include interest and depreciation on the construction cost of the entire plant. The lamps, fixtures, wires, cables, etc., may cost $125 to $200 per lamp; two-thirds of which will probably be in the wires and poles and the lamp standards, which should have a life of twenty or twenty-five years; while the lamps will probably be superseded by newer types in five years. An average of fifteen or twenty years of life for all outdoors equipment would probably be a fair estimate. The indoor plant—the generating machinery—would perhaps average about the same life, although some would place this at not to exceed ten years because of the improvements which are constantly being made and which would make it economical to scrap the machinery at intervals of not to exceed ten years, even though it be in good condition. Possibly an average life of fifteen years for the entire plant would be a fair estimate, or a depreciation charge of about 6 or 7 per cent.

It is not safe or fair to judge of the probable cost of municipal lighting, or what a company should charge, by costs or prices in other cities; but each case should be thoroughly studied in all its phases and opinion carefully formed by some one experienced in such calculations.

Art. 23. House Numbering

The numbering of houses is a municipal function which too often does not receive the attention that it should from officials. Convenience of both citizens and strangers is affected to a considerable degreee by the system of house numbering adopted; and the postal authorities require that some system be employed

where mail is to be delivered. It is evident that numbering cannot be left to individual property owners or chaos would result.

Numbering Systems. That system will be most satisfactory which can be applied uniformly to all streets and provide for all probable contingencies such as short or discontinuous streets, crooked alignment, etc. If in the numbering something more than mere avoiding of confusion is aimed at (as it always should be), and convenience in locating a building when its number is known be one of the aims, then a comprehensive system for the entire town based on some one general plan must be adopted.

A city laid out irregularly will require somewhat different treatment from one on the rectangular system. In the case of the latter, comparatively simple rules can be applied without variation.

A common plan, perhaps the simplest but far from the most desirable, is to begin numbering the houses on any given street at one end of that street and continue the numbers in succession toward the other end, allowing a number to each unit of a uniform number of feet, such as 25. (The New York plan.) Should this street at any time be continued in the opposite direction from the origin, as often occurs when it is found necessary to modify a poor street plan, the numbering must be revised throughout its length or the extension be given a new name. In this plan the house number gives little information concerning the location unless one knows where each street begins.

A plan which avoids the difficulty caused by street extension is to begin numbering one set of parallel streets at a river, lake or other body of water; but this can be employed by few cities, and can seldom be used for all the streets of any city. Also, as the shore line is seldom straight, corresponding numbers on parallel streets will not be opposite each other (as in the old Chicago system). This can be avoided by assuming a line or axis out in the water, parallel to the streets, which approximately parallels the shore, and begin numbering from this.

For streets which do not terminate at such a natural boundary, or for all streets in cities where there are no such boundaries, a street (preferably as straight as can be found) may be taken as an origin of numbering; in which case the numbers run each way from this axis and are designated East and West, or North and South. (Fifth Avenue, New York; State Street, Chicago; Main Street, Louisville are such axis streets.) A number of cities base their street numbering on two such axes which intersect at right angles, or approximately so, at or near the business center. The necessity of prefixing North, South, East or West to every street name in giving an address is cumbersome and occasionally forgotten or overlooked by outsiders in addressing mail, and may be avoided by changing the name of each street when it crosses the axis. A system can easily be devised in which the two names of a continuous street would suggest each other like Winter Street and Summer Street, in Boston. For instance, streets north of the axis might be given the names of states, and their continuations south of it the corresponding capitols. In Mexico City this idea has been carried to an extreme by giving a new name to each block; but this is not recommended.

This difficulty can be avoided in any city by taking the axes of numbering so far from the present center that the city is not likely ever to grow out to them; but this gives large numbers, and the city may grow beyond expectations. Considering everything, the use of different names for streets on opposite sides of an axis seems to be the best solution; but the use of the prefixes North and South, East and West is the most common.

It is almost if not quite universal in this country to place all odd numbers on one side of a street and even ones on the opposite side, consecutive numbers being opposite each other. It is also common to place the odd numbers on the same side, say the south or east, of every street in the city. In some cities, however, the odd number is placed on the right hand side of a given street when looking out it from the axis of numbering

The former plan seems preferable as it enables one to tell by a glance at the numbers of two adjacent houses whether he is on the east or west, the north or south of the numbering axis.

In making actual assignment of numbers, there are four or more general plans. In one, numbers are given in order to consecutive lots as they are at present divided. This is a very poor plan, as a later subdivision of lots necessitates the use of fractional numbers, as $127\frac{1}{2}$, $127\frac{3}{4}$, etc.; or of letters, as 127a, 127b, etc.; or the complete renumbering of the street periodically.

The second plan is to allot a number to each certain number of feet frontage as a unit. The most common unit is 25 ft.; although 20 is found in a number of cities; 10 ft. is used in the business sections of New Britain, Conn., Lowell, Mass. and other cities; and 18, 22, 30, 40 and even 50 ft. are found as units in various cities. Chicago, in adopting a new system in 1908, used 800 numbers to a mile, equivalent to 13.2 ft. frontage if making no allowance for streets.

A third plan is known as the block or Philadelphia plan. In this the numbers begin a new hundred at each intersecting street. The hundreds in the number of a building will then designate the number of blocks it is from the axis of numbering. If the streets in one or both directions are given numbers as names, the hundreds of a house number would be the name of the next street toward the center. Thus 623 would be between 6th Street and 7th Street. Where a city is laid out on the rectangular plan, or approximately so, this is probably the best plan for numbering. The few diagonal streets can follow the same system, taking their hundreds from the streets most nearly perpendicular to them. Where the blocks are short, the hundreds may change with every second street. In Louisville the hundreds change at thoroughfares, but not at short streets, and this is believed to be the general practice.

The fourth plan is on the coordinate system, and is especially applicable to cities laid out irregularly, where the use of the block plan would necessitate solving scores of special cases. In this, two axes at right angles are selected, these being two streets

if any two meet this requirement approximately; or if there are no such streets or it is desired to have all the numbers on one side of each axis, coordinate axes may be assumed either inside or outside the city. These are then drawn on an accurate map of the city. A length of street is assumed to be allotted to each lot number, taking this so small that the average lot front in any block will not be less than one and a half times this length. Fifteen feet is probably small enough for most cases. Some use greater lengths for residence sections, but this should be done with great caution, for many streets now devoted to residences may in time become business streets. If 15 ft. be assumed, then the city is laid off in 15-ft. squares (in practice 150-ft. squares may be used and the intermediate numbers interpolated) and the house number of any street crossing a given square is controlled by the distance of that square from the axis, and not at all by where the street begins or ends. The numbers on any given street are controlled by the set of ordinates more nearly at right angles to it. If these make an angle of 45° with the street, the lot length will be 21.2 ft., which is the maximum front possible between ordinates. If a street winds, it is assumed to have the direction of the line connecting its intersection with the numbering axis and its extremity; or its two extremities, if it does not reach the axis.

The individual lots may then be plotted on the map and each given the number of the ordinate nearest its middle; or the number at each end of each block may be taken from the map and the other numbers interpolated on the ground. The latter is the simpler and is sufficiently accurate for practical purposes. This is probably the best plan for cities having an irregular lay-out, where the Philadelphia plan is impracticable.

Practical Application. By a rather extensive investigation it was found that in 80 per cent of the cities studied the city engineer or engineering department had charge of the house numbering; clerks, assessors and other officials having it in charge in the others. In 90 per cent no charge is made for informing a property owner of his number. Several cities fur-

nish the figures for the house numbers free; others charge from 3 cents to 15 cents per figure and 5 to 10 cents per figure additional for placing. About one-third of the cities specify the size of figure, this being generally 2, $2\frac{1}{2}$ or 3 in. high. Enameled figures seem most popular, but aluminum, "non-corrosive metal," "lead composition," nickel-plated, oxidized copper, and tin painted are some of the required materials.

Many cities, perhaps most, give a builder his house number in issuing the building permit. For houses already built which have not placed numbers thereon, or in the case of a city which has just established a numbering system, several cities keep a book of notice blanks and stubs, notifying each owner and noting on the stub the street number, name, date sent, and date number is reported placed. (There is generally a penalty for not affixing the designated number to a house.) In Chicago, when the numbers were changed in 1908, notice was given by placing the new number on each bill sent out by the Water Department, and enclosing a notice calling attention to it and to the ordinance requiring the owner to affix this number to the building.

Art. 24. Street-Name Signs

Signs designating the names of streets should be placed at each street intersection, and on each corner of the intersection if they are to afford the greatest convenience. Their number is therefore considerable, and the selection of the most durable, effective and economical kind is worth some time and thought. The place and method of affixing such signs also should be seriously considered.

They should be plainly visible to those on the sidewalk, and to those riding in street cars or other vehicles; both by night and by day; should not be liable to be obscured or hidden by vines, awnings or other objects; should be so placed and constructed that they will not easily be damaged or removed by accident or design, or deteriorate by weather or age. They

should at least not disfigure the street, and if they can add to its appearance so much the better. Neither they nor their supports should obstruct the use of sidewalk or roadway more than is necessary.

It is desirable that they be readable from all four directions. When they face two directions only, it is common practice to have them face the roadway; but there are certain advantages in having them face down the sidewalk of each street. If so placed, those both on the sidewalk and in the roadway can read the name of the street as they approach it in time to decide whether to turn, and the former can also read the name of the street they are on without stepping out into the roadway.

Box Signs. The old-fashioned square gas lamp offered perhaps the best opportunity for displaying street names in all

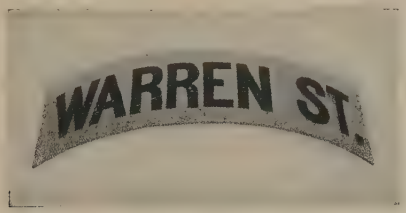


FIG. 83.—Curved Ground Glass Sign Used on Round Globe.

directions of any device used before or since, such names being placed, generally in open-work cast iron, on each of the four sides and visible both day and night. A similar square sign may be placed around the round globe of the boulevard lamp; but a better appearing one for such lamps consists of four quadrants of glass held in a light steel frame, each quadrant carrying a street name in ruby glass in a white ground glass background. These are used in northern New Jersey. New Haven, Conn. uses a similar sign, except that the letters are painted on the ground glass. In Washington, D. C. clear glass letters blown in ruby glass plates are used, held in a square copper frame and attached surrounding a light standard just below the lamp.

Boston uses a box sign composed of four wooden signs sur-

rounding a post, gilt letters on a black board. Washington and several other cities use a lantern type of sign, consisting of an ornamental box-shaped frame, in each side of which is a large square plate of ground glass on which the street name is painted in black, a small lamp burning inside to make it visible at night. Providence uses a cast-iron box sign which carries an interchangeable cast-iron name plate on each side, painted with blue letters on a white ground. These cost $8 each, complete. A wooden box sign is used by Syracuse, nailed to wooden posts, enameled iron signs being screwed to the wood sides. A standard sign used in San Francisco, surrounding a square post, is a box the sides of which are of enameled iron, white letters on a brown background, held in a neat bronze frame. These can be read across the street. They cost $1.75 erected.

FIG. 84.—Lantern Type of Street Name Sign Used in Washington, D. C.

Plate Signs. The most popular sign at present consists of a single plate of metal or wood, with the name painted or enameled on one side, or sometimes on both.

Wood signs are fairly durable if substantially fastened in place, but the paint used on many of them fades. Cambridge, Mass. uses a pine board 8 in. wide, framed with a pine molding, painted in black and lettered in gold leaf, costing $1.50 each. In Providence, R. I. nearly all signs are of wood with 3 in. black letters on a white ground; but these are to be replaced with enameled iron. In Boston wooden signs carry gilt letters on a black background. A great many cities use these wooden signs. They should not be fastened to round poles without gaining out the pole. A special pole or bracket to support them is preferable to nailing them to a tree or telegraph pole.

During the past few years the enameled steel plate has become the most common sign. Good vitreous enamels should be fused

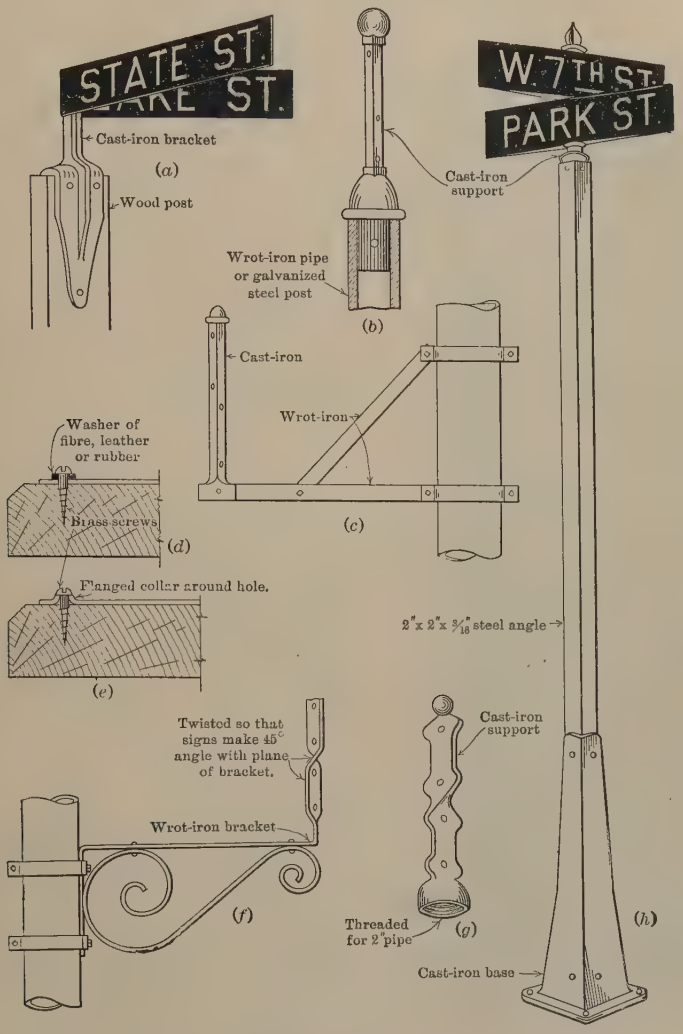


FIG. 85.—Devices for Supporting Enameled Iron Signs.

on at high temperature and permanent colors used. Cheap signs fade, tarnish, chip and the exposed steel plate rusts; but

reliable manufacturers will guarantee their signs for ten years against such defects. These plates should be fastened to a wood back to prevent bending, screws being used for the purpose, their heads separated from the plate by washers of leather, rubber or other yielding material; or the holes may be fitted with non-corrosive metal eyelets. More damage is caused to these signs by nails or screws so driven as to bend the plate and crack the enamel, than in any other way.

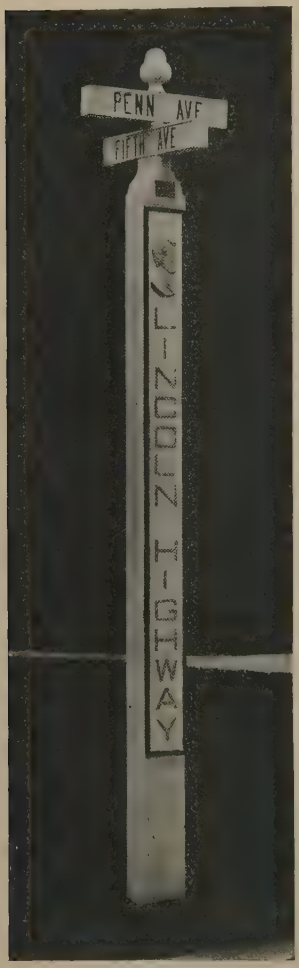


FIG. 86.— Pittsburgh Street Marker. Concrete Name Sign, with Concrete Letters Inlaid.

A better plan is to enclose the plate in a frame of steel or cast iron, the protecting of the edge preventing much of the breaking of the enamel, even by stones. When so framed, the plate may be enameled on both sides, and thus be read from both directions. Or two plates may be placed back to back, fastened together at the ends and slightly bowed so that a 1-in. steel supporting rod can pass vertically between them, the edges of both plates being held in a metal frame. Single-face enameled steel signs cost about 25 to 35 cents each (without frame or support), and double-faced ones about 40 to 60 cents.

Other plate signs are made of steel plates on which are brazed or riveted letters of aluminum, zinc or steel. Denver uses sheet-iron letters welded to a 14-gauge iron plate, the plate coated with black bicycle

enamel baked for three hours at 460°, the letters with bright aluminum bronze. These cost 5 cents per letter. Letters cut from sheet zinc are tacked to black wooden strips, or riveted or wired to metal plates. Some cities use cast-iron or bronze plates with the names cast on the face; but these are expensive.

A concrete sign plate has been introduced recently, letters of a black cement composition of permanent color and $\frac{3}{8}$-in. thick being embedded securely in the white concrete plate.

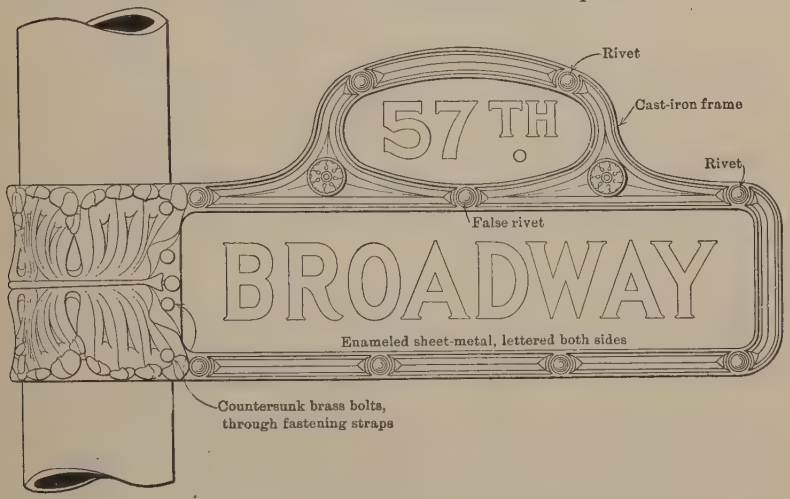


FIG. 87.—One Wing of New York Standard Sign.
White letters on a blue ground.

New York's latest standard consists of a steel frame with two wings at right angles, each wing or open frame carrying a double-faced enameled steel plate giving the name of the street, and above it in much smaller letters the name of the street which it faces, the whole being clamped to a light standard.

Thin tiles, one letter to a tile, set in a frame, have been used, but those of which the author has learned have checked or crazed and discolored with the weather. An indestructible sign is made of a soft steel plate into which holes are drilled so as to overlap and following the outlines of the letters, the holes

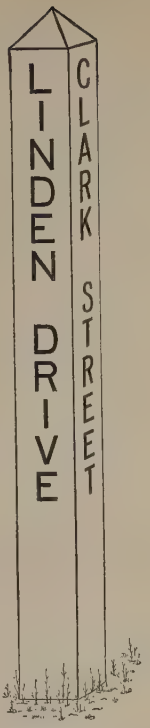
being filled with a white composition, which is left slightly depressed. The plate is painted black, and repainted in place by passing a paint-coated roller over it.

Other Kinds. Los Angeles, Cal., and Spokane, Wash., find a square wooden post, with the name painted vertically on each side, satisfactory for outlying districts. They are neat, easily read and cheap. Pittsburgh has a few concrete posts with lettering vertically down the sides, the letters similar to those of the concrete signs already described. In Chicago and Memphis the name is painted in white reading vertically down black-painted telegraph or other poles. Denver has used a bronze sign with letters in relief, made circular in plan and just fitting around an iron trolley pole, to which it is attached by screws.

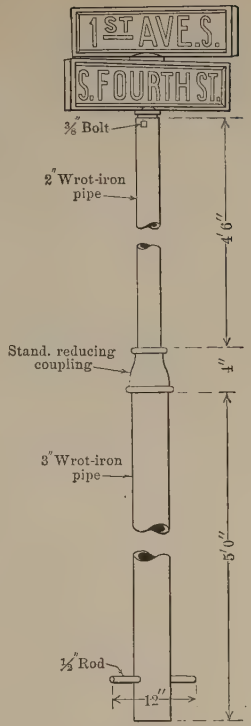
Sidewalk Signs. Names placed in the sidewalks have been used in a number of cities, generally at the sidewalk corner just back of the curb on each street. They are, in most cases, visible by night as well as by day, but are not suitable for a street with much foot traffic, nor one where much snow falls, either of which conceals them. They are generally placed to read from the roadway, which seems wrong, for it means that one must cross the road on reaching a street before learning its name, or else step into the roadway, pass the sign on the near side, and face around to read it. If turned the other way they could be read as one approached the crossing. In any event they cannot be read from vehicles.

The sidewalk sign is made by embedding in the fresh concrete a plate of bronze or other metal carrying the name in relief; letters of bronze; letters of tile; or stamping the letters into the concrete with brass dies, the depressed letters being sometimes filled with colored cement mortar.

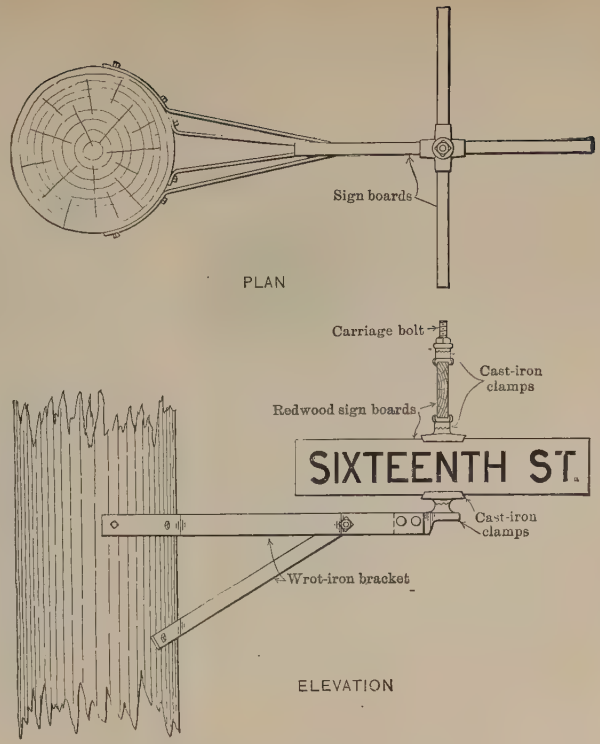
Similar to this is the placing of names on cast-iron gutter plates at crossings. Other cities paint or stencil the name on the face of the curb at the cross walk. The last is more likely than the sidewalk names to be covered with snow, must be sufficiently large to be read across the street to be of any service, and cannot be so read if there are many using the crossing or if there is snow



Square Wooden Post, White, with Black Lettering.



Double-faced, Cast-iron Signs, Clamped at any Angle on Pipe Post. Spokane.



Wooden Signs with Bracket as Used at Oakland, Cal. White Letters on Blue Sanded Background.

FIG. 88.—Various Street-name Signs and Methods of Supporting Them.

in the gutter. The painted sign on concrete is not very durable, and must be repainted once a year at a cost of about 25 cents. The latest variation is to use a section of hollow iron curb with a heavy glass front on which the name is painted, and containing an electric light.

FIG. 89.—Bronze Street-name Sign, Charleston, S. C.

FIG. 90.—Tile Street-name Sign, Knoxville, Tenn.

Lettering. A sign should be readable distinctly, by day or night, from sidewalk or trolley car. This means that the letters should be large, stand out distinctly from the background and each other, and be illuminated by the street lights (or a special light); and the location of the sign should be such that it can be found instantly.

The height of letters is generally between $2\frac{1}{2}$ and 4 in., 3 in. being common and, perhaps, the smallest which should be used. As to style, the block letter seems to be most easily read. The light lines in the Roman and some other styles are not sufficiently visible at a distance. The letters should be separated sufficiently, and with due consideration of their shape, to make each stand out distinctly. The colors of letter and background should so contrast as to assist in this. White and black; white and blue; silver gray or aluminum and black; gold and black;

aluminum bronze and green, are some of the combinations used. One of the important considerations is the permanance of the colors. Blue and white are most common for enameled iron signs, black and white for painted wood signs.

The location of the sign so that it will be illuminated by the street lamp is desirable. The box sign illuminated by the special lamp is expensive both to construct and maintain. Glass signs surrounding the regular street lamp are excellent for night, but the breakage is much greater than with other materials.

With an arc light suspended in the middle of an intersection, signs facing the roadway can be read at night if not in the shadows of trees. With the ornamental posts carrying two or more lights, either a plate sign, or a box sign surrounding the post, is easily visible; but with a one-globe electric light the solution for night reading is not so simple, without using an additional support for the sign.

The sign may be placed on the building line, as on a building or fence. On a fence the sign is too accessible to the mischievous or malicious; and if there be many using the sidewalk it is hidden from view. On a building, 10 or 12 ft. from the ground, is a better location. If the sign is not hidden by trees, vines, or awnings; if it is not made difficult to find by advertising signs surrounding it, and if a building offering these conditions can be found on every corner and its use is permitted by the owner, then the use of buildings leaves little to be desired. But all these conditions are seldom found. The location of street-name signs should be uniform throughout the city, or at least the business part, otherwise they are not readily found; and as few houses are placed on the building line corner in the residence sections, posts are generally desirable there. Uniformity of location generally requires a post or other special support in the business section also.

In the business section it is well to have the sign at least 9 or 10 ft. above the street so that it will be visible over the traffic; while on residence streets 7 or 8 ft. seems ample. The pole

should be set at the curb line so that trees will not obscure the view of it from the roadway. The sign should be illuminated by the street lights on as many faces as possible. The pole should be substantial, but not so heavy as to look unadapted to its light burden. It should be so securely set that it will not be heaved by frost, cannot be raised or revolved by boys or men, or thrown out of plumb by a blow. Wood decays too rapidly and must be painted too often to be economical, and iron is better. Tapering steel posts set in concrete are admirable; but iron pipe, 2, $2\frac{1}{2}$ or 3 in. in diameter, anchored in the ground by a tee and short nipples at the bottom, is satisfactory. On top of this is a cap adapted to holding the sign; or a 1-in. rod which passes vertically through one or two double-bowed or lenticular signs. Another style consists of a $2\frac{1}{2} \times 2\frac{1}{2}$ angle 9 to 12 ft. long, sunk 30 in. into the ground, at the top of which a sign plate is bolted to each flange. A tapering galvanized steel post 11 ft. long costs from 60 cents to $1.80, depending upon diameter and weight.

Where there are telephone or trolley posts, light standards or other posts on the corners, these are generally used, thus avoiding the obstruction of an additional post. If the post is wood, the sign is generally nailed or screwed on. If the post is iron or steel, it may be fastened on by screws or tap bolts, but straps or bands clamping the sign to the post are more common and probably more reliable.

Portland, Ore., employs a sign painter who paints all the street signs needed by the city. They are painted on iron strips or blanks (old enamel signs with the enamel knocked off are used when obtainable); two coats of white lead form the body, on which the letters are fielded in with cobalt blue, and the sign covered with two coats of varnish. The blanks cost $7\frac{1}{2}$ cents each, the paint and time of the painter about 10 cents. Baked enamel signs when bought cost $26\frac{1}{2}$ cents each.

Two or three cities have placed street corner directories at each of the down-town corners. The Los Angeles directories give the location of business houses for three blocks each way

FIG. 91.—Sign Painting Room and Work Done by Municipal Bureau of Portland, Ore.

and any prominent buildings in the vicinity, also the street cars passing the corner. There are one hundred or more in the city.

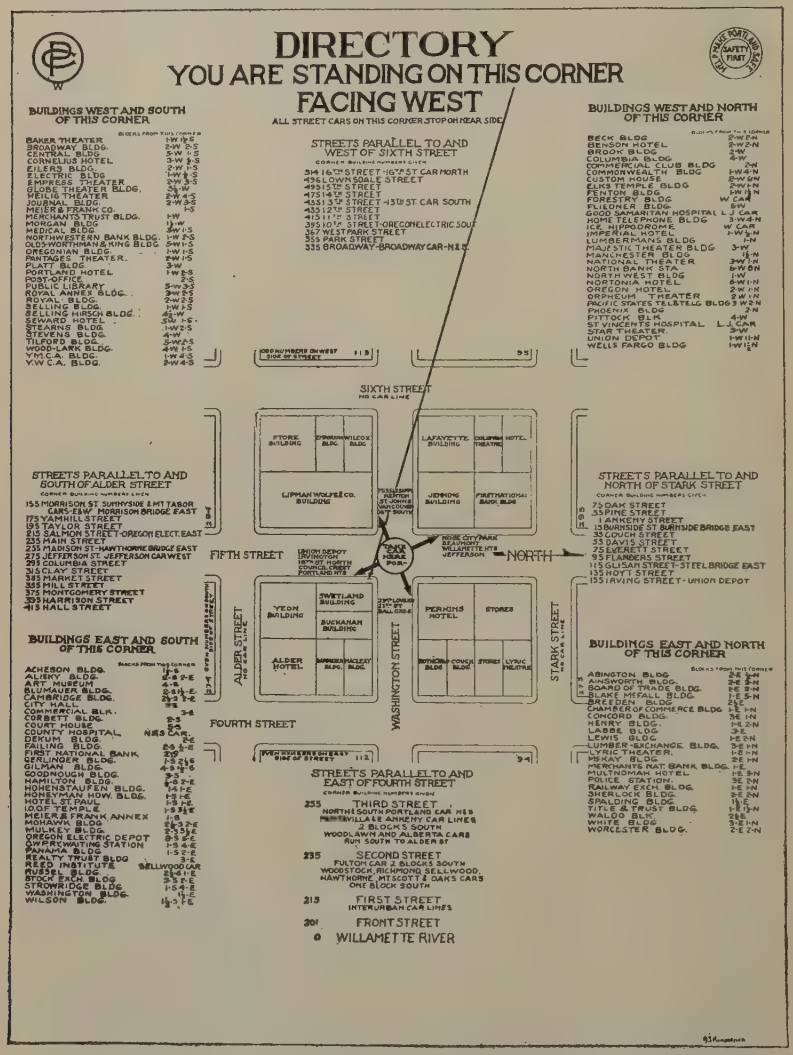

DIRECTORY
YOU ARE STANDING ON THIS CORNER
FACING WEST
ALL STREET CARS ON THIS CORNER STOP ON NEAR SIDE
BUILDINGS WEST AND SOUTH OF THIS CORNER
BUILDINGS WEST AND NORTH OF THIS CORNER
STREETS PARALLEL TO AND WEST OF SIXTH STREET
SIXTH STREET
NO CAR LINE
STREETS PARALLEL TO AND SOUTH OF ALDER STREET
STREETS PARALLEL TO AND NORTH OF STARK STREET
FIFTH STREET
ALDER STREET
WASHINGTON STREET
STARK STREET
NORTH
BUILDINGS EAST AND SOUTH OF THIS CORNER
BUILDINGS EAST AND NORTH OF THIS CORNER
FOURTH STREET
STREETS PARALLEL TO AND EAST OF FOURTH STREET
235 THIRD STREET
235 SECOND STREET
213 FIRST STREET
INTERURBAN CAR LINES
20 FRONT STREET
0 WILLAMETTE RIVER

FIG. 92.—Street Corner Directory, Portland, Ore.

These are a convenience to pedestrians and save the time of the traffic or other policeman at the corner.

CHAPTER VII

STREET CLEANING AND SPRINKLING

ART. 25. STREET CLEANING

PREVENTION is generally both cheaper and better than cure; and street cleaning would be greatly facilitated and cheapened if the city would prevent the throwing into the street of paper, fruit skins and numerous other matters found in the street sweepings of a city. The superintendent of street cleaning should consider it his duty to keep this fact before the citizens and their officials and do all in his power to prevent street littering.

The sidewalk is as much a part of the public street as is the roadway; much of the dirt—practically all of it, in fact—is brought to it from the street either by the feet of pedestrians or the wind; and the cleaning of the sidewalk would seem to be as much a public function as the cleaning of the roadway. A great many European cities and a number of those in the United States so consider it, the regular street cleaning force being required to clean the walks while cleaning the roadway. Snow would logically come under the same argument; but its removal is an emergency matter, to be expedited as much as possible, and property owners may well be pressed into service to assist to the extent of cleaning their own walks. Some cities and towns, however, remove the snow from sidewalks by use of special plows.

Theoretically streets should be kept clean by continuous work; but where there is little travel there is little to remove (except leaves during the fall), and going over them frequently in any practical way would involve more expense than the slight result obtained would warrant in most cases. The

general practice is to clean the business streets daily or keep them clean by continuous work, and to clean the others from three times a week to once or twice a year. Most cities where street cleaning has been systematized divide the streets into classes, one subject to daily cleaning, the others to cleaning once in two days, three days and six days respectively; while the outlying or little-used macadam streets are cleaned at much longer intervals.

FIG. 93.—Waste Paper or "Litter" Can, New York.

The appliances used for cleaning are the hand (or "push") broom; the machine sweeper, consisting of a cylindrical broom carried under a frame resting on four wheels and caused to revolve by chain or gear connection to the wheels; the pan scraper, used on asphalt or other very smooth pavement, like a wide dust-pan attached to a long handle; the squeegee, a rubber blade fastened between two stiffening plates, used to remove wet mud or slime; hose for flushing and washing off the dirt; and flushing machines, consisting of tanks carrying water which is forced out under pressure in a jet nearly tangent to the pavement.

There are numerous variations of these. Many hand brooms carry a scraper on one top edge. Several machine sweepers are

arranged to deposit the dirt in a box or cans carried on the same wheels or on a connected vehicle, the dirt being raised into them by a conveyor or by suction created by a fan. None of these has yet come into general use, although several have found favor with individual cities.

Special nozzles are used in several cities for flushing by hand, being attached to fire hose; some throwing a flat jet, some having valves in the nozzle for controlling the volume or shutting it off altogether.

Of the flushing machines there are two general types. In one, the water tank is air-tight, and when it is filled from a fire hydrant air is compressed in the top of the tank, which then furnishes the pressure for discharging the jet. The other carries a small pump on the rear, which furnishes the impulse to the water, which it draws from the tank. The former is the cheaper and at present the more common. The latter gives a uniform impulse to the jet, while with the latter the impulse decreases as the air expands.

A different type of cleaner is the squeegee flusher, which uses a much smaller amount of water, relying largely upon the scraping or squeegeeing effected by a number of heavy rubber blades set in a revolving cylinder on a very flat spiral, by which the dirt, mixed with the water discharged at the front of the wagon, is pushed forward and sidewise toward the gutter.

Machine sweepers, flushers and squeegees are either horse-drawn or motor-driven. The latter are apparently more economical where the mileage of streets to be cleaned is sufficiently great.

The dirt which is swept up by hand is in most cities placed in a can or bag, carried by a carrier or light steel frame on wheels, pushed by hand. In some cities the dirt is merely swept into piles, to be shoveled into carts later; but the dirt piles are scattered by horses, wheels or wind, and the practice is not to be commended. A few cities have tried a can set into the pavement in a receptacle which has a strong cover flush with the roadway or sidewalk surface, the can being lifted out to be emptied.

This is not in general use, one objection being the great number which would be needed or else the frequent collection from them by wagons.

The dirt collected by any of these methods must be removed to a dump or other disposal point. This is generally done by ordinary dirt carts or wagons. The cans or bags filled by the hand-sweepers are emptied into the carts. That left in windrows by the machine sweepers or the squeegees, or in the gutters by flushing, is swept into piles by hand and shoveled into the carts; as is that piled by the hand-sweeper where cans are not used. Generally one man besides the driver accompanies the cart to help empty the cans; but where the dirt has to be swept into piles and shoveled into the wagons, from two to six sweepers generally precede the wagon and one to four accompany it to shovel the dirt in. The wagon should follow the sweepers as closely as is practicable, for the dirt is soon scattered again by traffic and wind. The cans of the hand-sweepers may be less in number, and offer less obstruction and offense in the street, the more frequently they are collected; but the cost of collecting increases somewhat with such frequency.

Hand sweeping is done by either the patrol or gang system. In the former, each man is assigned a certain section or length of street to keep clean, and on this he spends the entire day, generally moving back and forth from one end to the other, sweeping up and placing in his can any dirt he finds. On his first trip each day he generally sweeps the entire area, which may take him a good part of the morning. When a can is filled, he wheels it to a designated point (preferably on a side street or alley near the middle of his section), where he leaves it and takes an empty one. At least once a day the collecting wagon makes its rounds and empties the cans. The length of section which a man can keep clean varies with the width of street, amount of dirt to be collected, amount and kind of traffic which interferes with his work, whether the same area is cleaned by night (hand sweeping is always done by day) by machine sweeping or flushing, the smoothness of the pavement, the frequency

of rains and other conditions. In Washington, D. C., the area covered by one man averages 13,000 sq. yds.; in New York, 9654; in Columbus, O., 16,200 sq. yds.

After going over his section thoroughly, the sweeper spends the rest of the day passing over it regularly from end to end

FIG. 94.—"White Wings" or Patrolman, with Can, Can Carrier and Broom.

sweeping up piles of horse-dropping, picking up papers, and removing any other dirt found. (This of course does not include dirt from building operations, which the ordinances generally require shall be removed by those responsible for it.) The average practice seems to be to require that the section be covered four times a day.

The cost of patrol sweeping in 1914 was 32.3 cents per 1000 sq. yds. in New York; 29.65 cents in Columbus; 28 cents in Lincoln, Neb.; 27 cents in St. Paul; and 42 cents in Cleveland in 1915. In New York, 0.124 cu. yds. of dirt was removed per 1000 sq. yds.; in Washington, 0.174 cu. yds.; in Columbus, 0.203 cu. yds.; in Lincoln, 0.085.

Washington employed 221 men on patrol sweeping, and 13 wagons to collect sweepings, covering 2,856,000 sq. yds. Columbus, O., used 37 men and 4 teams.

In gang sweeping, 5 or 10 men work in one gang under a foreman, generally accompanied by a team, and clean up the street as they go, which street is not cleaned again for at least a day, and often for several days. This is better adapted to outlying streets, or small cities, where the cleaning is periodic rather than continuous.

In gang sweeping, Columbus, in 1914, employed 6 men and a foreman, who averaged 28,190 sq. yds. per day, removing about 8 cu. yds. of dirt. Lincoln employed 16 men and 2 teams, which removed 12 cu. yds. per day from 142,000 sq. yds. This work cost, in Lincoln, $22\frac{1}{2}$ cents per 1000 sq. yds. for sweeping and piling and $5\frac{1}{2}$ cents for hauling. In St. Paul 1,138,000 sq. yds. were covered daily by 132 sweepers, 11 shovelers, 11 teams and 2 foremen, who removed an average of 120 cu. yds. daily, at an average cost of 27 cents per 1000 sq. yds.; brooms cost about $6 per day, or $4\frac{1}{2}$ cents per sweeper per day.

In hand-sweeping stone or other block pavements which have wide, open joints, the dirt should be swept toward the gutter, following the continuous joints, rather than lengthwise of the street. In some cities a sprinkling can is used to lay the dust just ahead of the sweeping, but wet dirt cannot be swept up so readily as dry, and this is not common.

Machine sweeping is done by night in the business districts in most cities, since the day traffic renders it impracticable; but in the less busy streets it may be done by day. The common practice is to sweep with a gang composed of a sprinkling wagon followed by two or three sweeping machines, which in turn are

followed by men which sweep the winrows of dirt into piles, which others shovel into carts for removal to the dump. The machines travel one behind the other in oblique formation, the first so as to sweep the dirt in a strip extending from the center of the street toward the right-hand curb, leaving it along the right edge of the strip; the second moves this winrow toward the gutter and also sweeps the adjoining strip; and if the width of the roadway requires, a third machine sweeps still a third strip, leaving all the dirt piled in a winrow in the gutter. Each machine will clean a strip about 6 ft. wide (the width covered is really about 2 ft. greater), so that three machines sweeping up one side of the street and down the other can clean a 36-ft. roadway.

In 1914 machine sweeping cost 26.4 cents per 1000 sq. yds. in New York; 25.7 cents in Columbus; 50 cents in Lincoln (35 cents for sweeping and piling and 15 cents for hauling). In Washington, 3 machine brooms, a sprinkler and 4 carts, with varying numbers of men (averaging about 12) piling, constitute a gang, which averaged 273,700 sq. yds. per day, or 91,233 per machine, removing about 0.1 cu. yd. of dirt per 1000 sq. yds. Columbus cleaned 133,000 sq. yds. per day per crew (but considers this too much for good work), removing 0.37 cu. yd. per 1000 sq. yds. In Lincoln each machine averages 80,000 sq. yds. per day, removing 0.34 cu. yd. of dirt per 1000 sq. yds. In Philadelphia in 1915 machine broom cleaning of granite block cost 24.6 cents per 1000 sq. yds.; brick cost 19.3 cents; wood block 16.6 cents, and sheet asphalt 15.9 cents. The machine broom cost $5.50 per day.

Flushing by hose in New York cost 57.3 cents per 1000 sq. yds., not including water. In Washington, 3 flushing machines each flushed off 100,000 sq. yds. a day. In Columbus each flushing machine cleaned 60,600 sq. yds. at a cost of 56.1 cents per 1000 sq. yds. (plus additional cost of catch basin cleaning). In St. Paul, four power flushers each averaged 59,250 sq. yds. per day of 16 hours at a cost of 31 cents, the force consisting of a foreman, 4 drivers and 2 gutter sweepeers.

Sweeping with machine brooms leaves fine dust on the surface and in depressions; when the street is sprinkled, this becomes a film of slime and probably even a greater amount of dirt is left on the street after sweeping than when it is swept dry. Providence, R. I., sweeps its streets without sprinkling. Sweeping with hand brooms removes the dust more thoroughly than machine sweeping. But the practically complete removal of this fine dust or slime can be effected only by flushing. On macadam streets which have received no surface treatment with asphalt or other bitumen, flushing is impracticable and oil sprinkling or water sprinkling is used to lay the dust.

Macadam streets (water-bound) can ordinarily be cleaned only by hoeing off the accumulated dirt occasionally, or by infrequent brooming. Too frequent brooming will remove the fine matter necessary for binding the surface stone, and induce raveling. Dust is continually being formed by attrition by vehicles and horse-droppings, however. To prevent this from being blown about, sprinkling with water, oil or other dust layers is the common remedy. When the dust becomes thick, however, water makes mud, oil makes a slimy ooze, neither is very satisfactory and very much greater amounts of either are required for effective results. An advantage of the use of a good road oil is that after several application, on a fairly clean road, the surface particles become so bound together that light brooming does not remove them, but only the superfluous dust. Such brooming can be done by hand broom or machine broom, using a rather soft splint rather than wire or rattan. The machine brooming is probably the less expensive.

Water-bound macadam, unless occasionally broomed, acquires a layer of dirt, especially along the edges and in the gutters, and grass grows in the latter; and both dirt and grass should be removed at intervals. This is generally done by hoeing by hand, most towns doing this work in the spring and some in the fall as well. A number use a road scraper where the gutter and sides of the road are dirt, unmacadamized, this being much

cheaper than hand work and giving a smoother surface. But a scraper used on macadam would be almost sure to pull out the surface stone to a greater or less extent.

Bituminous macadam, bituminous concrete, and good, unbroken bituminous carpet coat can be broomed, hoed or flushed like the hard-surface pavements. Any of these methods can be used with sheet asphalt, asphalt block, concrete, wood block, and brick or stone block with cement or bituminous filler. Brick or stone block with sand filler cannot generally be flushed with safety, but can be broomed or hoed.

Sidewalks are cleaned by the street cleaning force in a number of cities, although most of them confine such cleaning to the center of the city. In 1914 the area of sidewalks regularly cleaned in Chicago was 0.4 per cent as great as that of roadway; in Newton and N. Attleboro, Mass., 8 per cent, or about 12 per cent of the length; in Kansas City 27 per cent of the roadway area cleaned, or about 40 per cent of the length. This cleaning consists of hand sweeping and hose flushing. A few cities remove snow from the sidewalks on the main thorofares, but this is not the common practice.

Chicago Investigation. · The efficiency division of the Civil Service Commission of Chicago in 1912-1913 investigated the problem of street cleaning in that city, and certain of their conclusions were as follows: The time lost by street sweepers in dodging horses and automobiles where traffic is dense does not exceed 8 per cent of their hours of service, nor 2 per cent outside of the traffic center, and is caused more by congestion than by density of traffic.

Traffic density is in direct relation to the amount of street dirt to be removed, and is the most important factor in deciding the number of cleanings a given pavement must receive to maintain a certain standard of cleanliness. On an average 1000 horses excrete 500 gallons of urine and 10 tons of dung during a working day of eight hours.

" The number of cleanings per week which any street having permanently improved pavement will receive is expressed by the

equation: $N = \frac{E}{CW}$, in which N is number of cleanings per week: E equals total number of horse-drawn vehicles per eight-hour day; W equals width of roadway in feet, and C is a constant of cleaning." W will generally be the available width, which may be less than total width because of standing motor vehicles or other obstructions. The values of C used in Chicago were as follows: Densely settled portion of the city, 2.1 for residence and 2.6 for business and manufacturing districts. Outlying portions of the city, 2.5 for residence and 2.8 for business or manufacturing districts. Minimums were adopted of three cleanings in the central part and one in the outlying districts on hard pavements. Other minimums were adopted for special cases.

The Chicago efficiency survey found that more area of asphalt pavements could be cleaned by a man in eight hours than of any other kind in use, the relative amounts of other kinds which could be so cleaned being as follows:

Asphalt in good condition	100
Asphalt in fair condition	90
Asphalt in poor condition	80
Creosoted wood block in good condition	100
Brick in good condition	74
Brick in fair condition	47
Brick in poor condition	37
Granite in good condition	62.5
Granite in fair condition	47
Granite in poor condition	37.5

A street car right-of-way was approximately 15 per cent more difficult to clean than the same kind of pavement where there is no track.

Probably the best which could be done by an able street cleaner on 100 per cent pavement would be 34,000 sq. yds. in eight hours, but 29,000 probably could not be exceeded in routine work. This is for asphalt or creosoted wood block in

good condition. For brick in poor condition the percentages above would give 10,730 as a reasonable area to be cleaned.

It was found that a street cleaner collects an average of about $1\frac{1}{2}$ cu. yds. of street dirt in eight hours on improved pavements and about 2 on macadam, where these are cleaned on the regular cleaning schedule.

Milwaukee Investigation. The Milwaukee Bureau of Municipal Research, after a study of street cleaning in that city in 1914, reported that rotary brooms cost $250 each and lasted about ten years; cost $20 per year for minor repairs and replacements; and six new brooms cost 8 cents per pound for bamboo, of which 50 lbs. was required for each broom, and forty-eight hours labor in filling the brooms; giving a total cost per season of $92.25 each. Operating a broom requires a driver, team and two hand sweepers. These machines averaged 40,000 sq. yds. cleaned per day. The streets are sprinkled ahead of the sweeper at a cost of $5.90 per day.

In flusher cleaning, four machines are used in staggered double formation cleaning the entire width of the street. A machine costs $1500, the wagon and tank figured at $1000 and the engine at $500. Figuring depreciation on wagon and tank at 10 per cent and on engine at 25 per cent, interest at $4\frac{1}{2}$ per cent, gives fixed charges of $292.50 per year. For painting $20, and for hose and couplings $15, gives annual charge of $327.50. The daily cost includes team and driver, one laborer, water, gasoline and oil. The machines cleaned from 30,000 to 40,000 sq. yds. a day.

Squeegees cost $1250 each, of which $140 is for the roller. Depreciation and $4\frac{1}{2}$ per cent interest was estimated at $237.25 per year; painting, $20; hose and couplings, $15; giving an annual cost of $272.25. Operation requires team and driver, hand sweeper and water. These machines averaged 377,700 sq. yds. cleaned per day.

Art. 26. Removal of Snow

Removing snow from roadways is very costly and is not generally attempted in any but business streets in large cities. Its removal from street railway tracks is necessary, but is generally performed by sweeping or pushing it to the side of the roadway. When this is done, the railway company should be required to level off the snow so deposited. If the fall is deep, and especially if the roadway is narrow, it is very desirable to remove this snow from the street altogether to avoid the danger to teams of a bank of snow on each side of the track. This the railway company should do, as it is the presence of their tracks which occasions the necessity.

In some northern towns where the snowfalls are heavy, the snow is packed down by passing a heavy horse roller over it, thus fitting it quickly for use by sleighs.

Snow on sidewalks is generally shoveled into the street or onto the outside of the sidewalk space by the occupants of abutting property. In some cities snow plows (several are on the market designed for this use) are used to clear a path 4 to 8 ft. wide, shoving the snow to the sides. Where the sidewalk traffic requires paving from property line to curb, all this should be cleaned. Where there is a sodded or planting strip, 2 or 3 in. of this should be cleared on each side of the paved strip, to absorb the water that will be formed later by the melting of the snow and would otherwise collect in lakes or run in streams in the cleared strip.

The snow should be kept cleared away from fire hydrants, and from street crossings, street car stopping places, and letter box posts and other objects used by the general public. Gutters should be cleaned out before a thaw or warm rain.

Where snow is removed from the street there are two general methods—by shoveling it into carts, and by scraping or shoveling it into sewers. In some cases the carts dump the snow into sewers, in others into a river from a bridge or dock. St. Louis

and Pittsburgh have constructed manholes especially for sewer dumping. In New York and Philadelphia ordinary manholes are used. When snow is dumped or shoveled into sewers care should be taken that it contains no dirt, sticks, stones or other large or heavy objects which might cause deposits in the sewer. If this is done and there is plenty of sewage flowing to melt the snow, there seems to be little objection to the practice and it is much cheaper than carting. If there is not sufficient sewage, water from a fire hydrant may be turned into the manhole by means of fire hose. It was found in New York that snow can

FIG. 95.—Snow Plows, New York.

safely be dumped by the wagon load into sewers carrying 10 cu. ft. per second of water; and by pan scrapers where the flow is at least 3 cu. ft. per second.

For scraping snow into sewers the regular street cleaner's scraper is generally used. With this, 6 to 8 cu. ft. of freshly fallen snow can be carried to the manhole at each trip. After the snow is packed or frozen it may require to be loosened by picks. A horse-drawn " Fresno " or other scraper may be used for hauling snow to manholes or cleaning out gutters.

Another method is to pile snow and allow it to melt with the next thaw. This is applicable only south of the northern tier

of states, where thaws and snows generally alternate. The snow may be piled in the center of the street, in long ridges with occasional breaks for crossing over, or in piles at intervals; or along one or both sides of the roadway, according to the width of roadway, character of abutting property, etc. In general middle piling is preferable where there are retail stores or much hauling of freight to and from the abutting buildings; while piling along the sides is more favorable for through traffic.

Removing snow by water applied by fire hose is practiced in Scranton, Pa., men stationed 10 or 15 ft. apart loosening the snow and ice, which is washed into catch basins. In thirteen hours 24 men cleared 3 ft. depth of snow from 14,440 sq. ft. This would not be applicable if the temperature was much below freezing.

Removal by melting is theoretically practicable at a cost of 29 or 30 cents per cu. yd. of loose snow (hauling costs 24 cents in New York and removal by sewers 12 cents), using coal costing $6.25 per ton delivered on the street. It has not been tried in practice. One objection to this and all methods requiring special apparatus is that such apparatus must be provided in large quantities (more than 2000 boilers would be required for New York City), which must be stored during the entire year, and interest and depreciation incurred, for use during five or ten days each year.

Sidewalks should be cleaned by the occupants of abutting property, and if they do not do it, by city forces. Most cities and towns have an ordinance requiring occupants to clean their sidewalks within a given time (varying from six hours of daylight to twenty-four hours) after a snowstorm stops, and providing that sidewalks not cleaned at the end of that period will be cleaned by city forces and the delinquent required to pay the cost and (in some cases) a fine for failure to obey the ordinance.

Leon F. Peck, superintendent of streets of Hartford, Conn., states that in New England cities there is an average of one mile for each 10,000 population from which snow removal is required, in addition to those cleaned by the street railways. This is

handled by about 25 men and 15 teams for each mile cleaned, at a cost of 12 to 30 cents per cu. yd.

The plan now adopted by the large cities is to begin removing snow as soon as it reaches a depth of 3 in. If shoveled into sewers, the snow is then free of matters which might clog the sewers, which matters accumulate as the snow lies.

For temporary piling, motor-driven snow plows are considered better than shoveling; for enough men can be induced to keep the plows going during the storm, but not enough to keep the street clear by shoveling. When the men can be put to work, they shovel into piles the snow which the plows have shoved to the center or sides of the street. Philadelphia used 60 plows in 1916 and New York used 84.

Art. 27. Street Sprinkling and Oiling

Sprinkling with water lays dust temporarily and cools the pavement and the air above. The water evaporates in an hour or so in hot weather, and sprinkling must be repeated several times a day to be effective. Ideal sprinkling would be that which kept the dirt on the street from actually drying, but which never wet it to a mud. The water should not strike the pavement with force nor in the form of a stream, especially if it be a macadam pavement. This would require frequent sprinkling with a fine spray—a soaking once or twice a day is almost worse than no sprinkling. Shade trees on a street reduce the necessity for frequent sprinkling by decreasing evaporation.

Sprinkling carts are generally drawn by two horses, although some automobile and trolley sprinklers are used. (Springfield, Holyoke, Lynn and Quincy, Mass.; Hartford and New Haven, Conn.; Louisville, San Antonio and other cities have used trolley sprinklers with an arm that reaches from car to curb.) Sprinkling carts usually hold 500 to 1200 gallons and are filled at frequent intervals at fire hydrants (which should not be allowed) or at special attachments to the water mains provided for the

purpose. On the Pacific coast many of the carts used hold 800 to 1500 gallons, have 6-in. tires, are drawn by four horses, and on a back platform have a gasoline engine and pump for filling them by raising water from rivers, wells, etc. Hand pumps are used for this purpose in some towns or outlying districts where there are no water mains.

Sprinkling is done by the city, or by contractors who are paid either by the city or by the abutting property. In the larger cities, city forces generally do the sprinkling, either at public expense or assessing the cost against the abutting property. In small cities and towns it is common for private parties to contract with the property owners individually.

Cost. The amount of water used varies considerably with kind of pavement, climate, length of sprinkling season, etc. The following figures have been reported by different cities: Indianapolis, 2.6 gals. per foot of 50 ft. street per day, or 6.8 gals. per sq. ft. per season. St. Paul, 2.2 gals. per foot of street per day. Oakland, Cal., 0.4 gal. per foot per day. The cost in Rochester one year was 1.56 cents per sq. yd. per season; in St. Paul, 0.2 to 0.33 cent per week per lineal foot for dirt and stone block, and 0.4 cent for asphalt. In Indianapolis, sprinkling three times daily, including Sundays and holidays, from April 1 to October 1, cost 0.2 cent per sq. ft., or 6 cents per foot frontage. In Cincinnati the cost was 2 cents per front foot per month. In St. Paul the cost in 1914 was 2.94 cents per front foot, two sprinklings per day for eight and one-half months (no sprinkling 30 per cent of the time).

Assuming 2 gallons per lineal foot per day, the roadway covered once by two trips, and two sprinklings per day, giving four trips over each lineal foot of street, an 800-gallon cart would travel 1600 ft. in emptying one filling, requiring about eight minutes; going to the nearest sprinkler hydrant and filling might require seven minutes, giving fifteen minutes per load, or 32 loads per day, covering $2\frac{1}{2}$ miles of street twice. At $10 per wagon per day, 140 days sprinkling (not needed because of rain 25 per cent of the six-month season), this would give a cost

of $5\frac{1}{4}$ cents per season, in addition to the water, or $2\frac{5}{8}$ cents per foot frontage.

In St. Paul, in 1914, a test was made with an automobile sprinkling cart holding 1260 gallons and costing $6300. The average time required to fill it from a 2-in. standpipe was seven minutes, and 1200 gallons were discharged in eight minutes, traveling at $7\frac{1}{2}$ miles per hour and sprinkling the entire width of roadway at one sprinkling. Allowing five minutes loss of time per tank load, 30 miles could be sprinkled in ten hours. It was estimated that it would cost $463 a month to operate the auto sprinkler, including interest, maintenance and depreciation. St. Cloud, Minn., sprinkled 34 miles a day, at one load a mile, with the same kind of sprinkler.

Horse-drawn sprinklers cost $150 to $250 each, depending on make, size and materials used. A first-class sprinkler of 750 gallons capacity cost $245 in St. Paul in 1914.

Sprinkling with oil has become quite general for macadam and gravel streets in recent years. (It must not be used on asphalt or other bituminous surfaces, as the oil would soften the pavement.) It finally results in so saturating the surface dust that it does not blow about; but such saturated dust does not make a permanent surface and will make mud after heavy rains; therefore as much dust as possible should be removed before oiling. Also the street surface should be made and kept free from depressions, for these will retain puddles of oil and of rain water which traffic will work into mud, increasing the size of the depression. Before beginning oiling, the surface should be leveled smooth and compacted and the dust removed. A crown giving a slope of 1 in. per ft. is desirable.

Oils containing 40 to 50 per cent of so-called asphalt are best. The greasy characteristics of the ordinary petroleum oil are objectionable for any but earth roads (not including sand or gravel). About $\frac{1}{3}$ to $\frac{1}{2}$ gallon per sq. yd. is generally applied (the latter for first or infrequent applications) once to three times a season. The oil may be distributed with an ordinary water sprinkling cart. Carts designed especially for sprinkling oil, of 500 to 750

gallons capacity, can be obtained for $500 to $1000. These can be adjusted to distribute the oil at different rates per sq. yd., and some with considerable force to assist penetration of the road surface. (This force is also said to raise any dust on the surface and thus apply the oil directly to the compacted road metal.)

To prevent the unpleasantness of oil on the crosswalks, these may be covered with dust before oiling, and the oil-soaked dust shoveled off after the oil has soaked into the road. It is desirable to give a light spreading of sand over the oil after it has stood for about a day. St. Paul uses for this purpose sand-spreading wagons of $1\frac{1}{4}$ cu. yds. capacity costing $375 each. Care should be taken not to use too much sand, or this will make an unsubstantial "carpet" or layer which will move under traffic into waves and pockets, peel off in patches and possibly ruin the road. Sand, not dust, should be used, and not more than 1 cu. yd. for each 500 or 600 sq. yds. ($=\frac{1}{16}$ in. thickness).

After the road has been in service for a few days it may be desirable to add an additional light covering of sand over small patches where oil is picked up by wheels.

Oiling generally is desirable once a year, in the spring after the road has been put into shape, but before it has acquired a layer of dust; and two or three coats may be necessary the first year.

Oil costs very much less in tank cars than in barrels, even if demurrage is paid on the cars while the oil is being used. By running the car onto a trestle (a coal trestle is sometimes available) or an embankment 8 ft. or more high, the oil can be run into the sprinkler wagon by gravity from the tap in the bottom of the tank car, or into a storage tank set high enough to supply the wagons by gravity. Otherwise the oil must be pumped from the car.

Oiling a 25-ft. roadway costs about $\frac{1}{2}$ to 2 cents per lineal foot for cleaning preparatory to oiling; 5 to 7 cents for unloading, hauling and distributing the oil (including sanding); oil and sand $3\frac{1}{2}$ to 6 cents (with oil at 4 cents per gallon); a total of 9 to 15 cents per lineal foot, or 3.2 to $5\frac{1}{3}$ cents per sq. yd. per oiling.

CHAPTER VIII

DISPOSING OF CITY WASTES

Art. 28. Composition of Refuse

City waste materials consist of those animal, vegetable and mineral solids, and dirty water, which are discarded by citizens as no longer useful or desirable to retain on the premises. In general they are classified as garbage, ashes, rubbish and street sweepings (included under the general head of refuse), and sewage; to which must sometimes be added trade wastes, snow, dead animals, manure and night soil.

Garbage consists of animal and vegetable refuse from the kitchen and table. Rubbish comprises paper, shoes, glass, metals and other waste solid matters which are not putrescible and are not included under the head of garbage or ashes. Various municipal ordinances, for purposes of collection and disposal, adopt different classifications, including bottles and metals under the head of ashes, for instance, because they can be used safely for filling low land; and classifying tin cans with garbage because of the putrescible matter they contain. Such classifications are not correct but are justifiable because of convenience.

Each of the above classes of wastes may be collected and disposed of separately, or two or more may be combined. In the United States most cities make two or more classifications. In England garbage, ashes and small rubbish matters are generally combined in one household receptacle and disposed of together.

Composition of Garbage. The composition of garbage varies in different sections of the country, in different sections of the same city even, and in different seasons of the year, according to the amount and kind of vegetable matter used as

food, the amount of meat used, the economy of the householders, etc. Analyses taken in New York and neighboring cities at different times show approximately 70 to 80 per cent moisture, 16 to 30 per cent animal and vegetable solids and 2 to 7 per cent non-combustible matter. If the water be excluded, the solid matter may contain 6 to 9 per cent of grease, $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent of phosphoric acid, $1\frac{1}{2}$ to 4 per cent of nitrogen. The poorer the people, the less the amount of nitrogenous matters and grease; summer garbage is low in these matters but high in melon rinds, corn husks, etc.

In most cases the garbage pail receives other matters. Thus in Trenton, N. J., but 84 per cent was found to be animal and vegetable matter, 12 per cent paper, 3 per cent rags, carpet, etc., 1 per cent rubbish. The amount of water may be enormous, especially if the householder is permitted to place dish water in the garbage pail and if rain be allowed to fall into it; also melon rinds contribute a large amount of water in the fall. What the authorities should permit to be placed in the garbage pail depends upon the disposition to be made of the garbage. If it is to be burned, paper, shoes, cloth in various forms, and other combustibles are an advantage. If to be fed to swine or used as fertilizer these are generally prohibited. In either case bottles and cans are objectionable; but as they generally contain putrescible matters (they should be washed clean and placed with the rubbish, but it is impossible to enforce this), sanitation would seem to demand that they be treated with the garbage. As a general rule all rapidly putrescible wastes (except sewage) should be treated as garbage. Several cities require garbage to be drained (to prevent freezing, reduce bulk and nuisance, and also to render combustion easier if this method of disposal is employed), and a few require it to be wrapped in paper after draining, which reduces the soiling of the garbage pail.

The weight of garbage has been variously reported as between 1000 and 1800 lbs. per cu. yd. Water weighs 1786 lbs. per cu. yd., and most garbage contains at least 10 to 15 per cent of free water. The solid matters in garbage generally weigh less

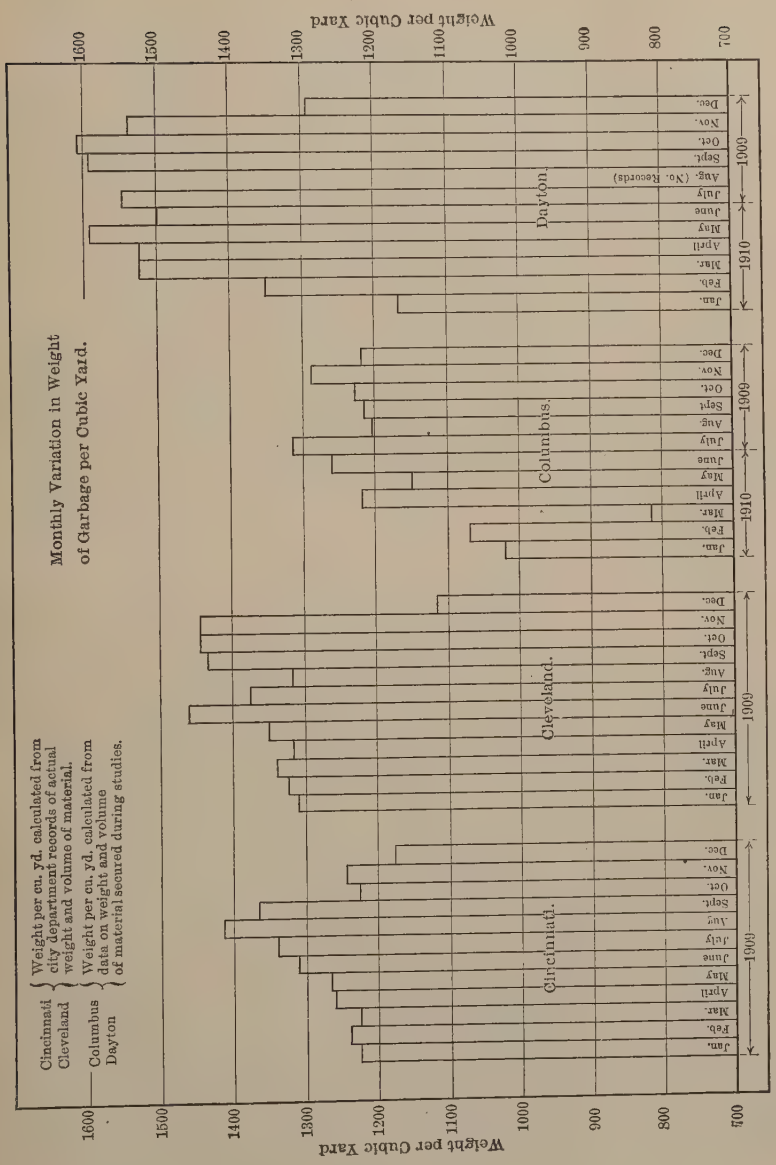


FIG. 96.—Monthly Variation in Weight of Garbage in Four Ohio Cities.

than this. About 1500 to 1700 lbs. may be taken as a general average, including water.

The amount of garbage per capita per year, as reported by a number of cities, varies from 100 to 375 lbs., probably averaging about 200 lbs., or 0.6 lb. per day (excluding Sundays, when collections are not made in most cities). The amount is very indefinite because of the presence of rubbish and variations in water con-

TABLE XXI

ANALYSES OF GARBAGE OF FOUR OHIO CITIES

	CINCINNATI, *a*			CLEVELAND, *b*		
	Ave.	Max.	Min.	Ave.	Max.	Min.
Per cent moisture	76.6	79.3	74.5	75.6	78.9	72.7
Percentage of dry matter						
Ash	15.65	20.35	12.71	13.12	15.06	10.90
Combustible matter	84.35	87.29	79.66	86.88	89.10	84.94
Ether extract	17.15	22.64	14.52	15.85	20.72	12.53
Phosphoric acid (P_2O_5)	1.26	1.91	0.71	0.99	1.38	0.65
Kjeldahl nitrogen	2.74	2.92	2.53	2.61	2.84	2.37
Potash (K_2O)	1.18	1.34	0.88	1.23	1.49	1.06
B. t. u. per pound of dry matter	8558	9186	8272	8459	8755	7883

	COLUMBUS, *c*			DAYTON, *d*		
	Ave.	Max.	Min.	Ave.	Max.	Min.
Per cent moisture	76.4	79.7	73.2	80.6	83.3	78.2
Percentage of dry matter						
Ash	13.98	17.66	10.56	13.19	16.15	11.50
Combustible matter	86.02	89.44	82.34	86.81	88.50	83.85
Ether extract	16.74	19.06	14.53	19.77	24.41	16.15
Phosphoric acid (P_2O_5)	0.95	1.63	0.41	1.00	1.42	0.72
Kjeldahl nitrogen	2.50	2.93	2.23	2.65	2.96	2.30
Potash (K_2O)	1.08	1.34	0.78	1.03	1.42	0.68
B. t. u. per pound of dry matter	8448	8839	8194	8776	8928	8179

a—Averages of ten samples, taken once a month from September to June. *b*—Averages of 28 samples, taken once a month from May to June of the following year and 14 additional ones. *c*—Averages of 31 samples, same as *b*, but with 17 additional ones. *d*—Averages of 30 samples, same as *b*, but with 16 additional ones.

TABLE XXII

QUANTITY OF GARBAGE COLLECTED, BY MONTHS

POUNDS PER CAPITA PER MONTH

City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Cincinnati	10.3	10.1	9.8	13.4	13.2	17.6	24.0	23.4	26.6	15.9	14.6	14.5	193.4
Cleveland	13.0	11.0	11.8	10.9	11.7	14.6	14.6	16.3	17.8	16.0	14.9	11.9	164.5
Columbus	9.4	8.6	9.4	15.4	13.4	13.8	19.2	20.6	27.4	17.0	15.0	18.4	187.8
Dayton	13.9	14.4	15.8	14.9	15.2	17.3	21.6	22.7	23.3	18.9	17.1	16.1	211.0

tent, as well as in actual quantities of food matter discarded. Also because few cities keep an accurate record of the amounts collected.

The variations in amount and composition in the same city at different times and in different cities in the same section of the country are shown by the accompanying tables, prepared from data collected by the Ohio State Board of Health. Similar data for ashes and rubbish collected by the board from the same four cities—Cincinnati, Cleveland, Columbus and Dayton—are given under those respective heads.

Composition of Ashes. Ashes are practically free of organic matter except as matters are mixed with them which should be with the garbage. Household ashes contain more or less unburned coal—in New York about 20 per cent (as high as 50 per cent from some districts), but generally less in smaller cities. Ashes weigh about 0.65 ton per cu. yd. The amount varies

TABLE XXI A

MONTHLY VARIATION IN COMPOSITION OF GARBAGE OF COLUMBUS, OHIO

AVERAGES OF ANALYSES OF COMPOSITE SAMPLES

Month	No. of Samples Included	Average Weight per Cubic Yard	Percentages			Calorific Value B. T. U.	Percentages			
			Moisture	Ash	Combustible Matter		Ether Extract	Phosphoric Acid as P_2O_5	Nitrogen Kjeldahl Method	Potash as K_2O
May	2	1,177	73.2	4.09	22.61	2,237	5.12	0.25	0.67	0.25
June	8	1,308	77.5	3.39	19.17	1,891	4.05	0.24	0.60	0.28
July	2	1,316	77.9	3.56	18.55	1,842	3.93	0.18	0.54	0.29
August	2	1,206	79.7	3.05	17.26	1,679	3.26	0.32	0.47	0.25
September	1	1,216	79.6	2.50	17.90	1,738	3.03	0.15	0.53	0.23
October	1	1,232	77.3	3.14	19.56	1,894	3.44	0.24	0.60	0.18
November	1	1,289	76.3	3.09	20.61	1,984	3.87	0.22	0.55	0.26
December	8	1,221	75.7	3.39	21.07	2,085	3.96	0.32	0.62	0.25
January	1	1,022	74.1	2.78	23.12	2,289	4.51	0.23	0.58	0.27
February	1	1,072	76.3	2.60	21.10	2,091	4.25	0.17	0.57	0.26
March	1	813	76.8	2.43	20.57	2,019	4.00	0.09	0.52	0.23
April	1	1,222	73.9	4.61	21.49	2,139	4.19	0.23	0.68	0.23
May	1	1,120	76.2	3.65	20.15	1,987	3.46	0.22	0.61	0.32
June	1	1,213	75.4	3.92	20.68	2,046	4.31	0.26	0.72	0.24
Average	....	1,173	76.4	3.30	20.27	1,994	3.96	0.22	0.59	0.25
Maximum	....	1,316	79.7	4.61	23.12	2,289	5.12	0.32	0.72	0.32
Minimum	....	813	73.2	2.43	17.26	1,679	3.03	0.09	0.47	0.18

from about 0.8 ton per capita per year in large northern cities to 0.1 ton in some southern cities. The ashes of Cincinnati in 1910 contained 33 per cent combustible matter (calculated with moisture content disregarded); Cleveland, 25.6 per cent, and Dayton, 26.6 per cent. The calorific values were 3348, 2113 and 3119 heat units, respectively.

Composition of Rubbish. No readily putrescible matter should be classified or permitted with rubbish. Much of it

TABLE XXIII

ANNUAL PRODUCTION OF GARBAGE IN REPRESENTATIVE CITIES, YEAR 1910

Cities	Population	Tonnage	Pounds per Capita
New York, Manhattan, Bronx and Brooklyn	4,396,873	346,000	157
Cleveland	560,663	44,747	160
Detroit	465,766	39,183	168
St. Louis	687,029	56,500	164
Boston	670,585	63,451	188
Cincinnati	364,463	36,000	196
Columbus	181,548	17,534	192
Washington	331,069	39,183	236
Chicago (except 8th and 33d Wards)	2,062,889	99,537	96.5

TABLE XXIV

MONTHLY VARIATION, IN PERCENTAGES, OF GARBAGE PRODUCED ANNUALLY IN SEVERAL LARGE CITIES

Month	Cleveland	Columbus	Cincinnati	Washington	New York	Detroit	Chicago
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
January	7.00	6.28	5.34	7.50	6.30	7.30	5.50
February	6.00	5.67	5.20	6.60	5.70	5.85	5.30
March	7.80	6.36	5.16	7.20	7.00	6.60	5.30
April	7.85	6.70	6.92	7.55	8.10	7.55	6.50
May	7.50	7.78	6.80	8.45	9.25	8.20	7.40
June	9.00	7.82	9.08	7.80	9.37	7.90	8.10
July	8.65	9.40	12.40	9.20	9.55	8.80	10.50
August	9.60	12.24	12.10	11.70	9.86	10.40	12.40
September	10.70	12.95	13.80	10.90	10.89	10.10	12.30
October	9.80	9.20	8.20	8.50	9.18	10.30	10.60
November	8.30	7.83	7.50	7.40	7.80	8.10	8.60
December	7.60	7.77	7.50	7.20	7.00	8.90	7.50
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

consists of wood, cloth, paper and other combustible matter, but there are also glass and metals. One analysis of New York rubbish gave 35 per cent marketable, 60 per cent combustible unmarketable and 5 per cent incombustible unmarketable. Some cities report 0.1 lb. per capita per day and others as high as 0.6 lb., while in several there is none collected, but it is burned or otherwise disposed of by the householders. It may weigh anything between .01 ton and 0.5 ton per cu. yd.

Composition of Street Sweepings. These consist of pulverized stone, earth and horse droppings, with more or less of all kinds of matter which are unlawfully thrown into the street, such

TABLE XXV

MONTHLY VARIATION, IN PERCENTAGES, OF RUBBISH PRODUCED ANNUALLY IN SEVERAL CITIES

Month	Buffalo	Rochester	Pittsburg	New York
January	8.62	8.50	8.27	6.43
February	8.43	7.58	5.83	6.28
March	7.78	8.05	7.92	7.54
April	9.79	8.78	9.44	8.26
May	11.87	8.90	10.92	8.31
June	10.38	8.00	9.63	8.63
July	7.69	9.35	8.26	8.94
August	7.24	8.87	7.84	9.54
September	7.30	7.99	7.57	9.68
October	8.95	8.94	9.48	9.80
November	6.54	7.49	8.33	8.77
December	7.31	7.75	6.49	7.82

TABLE XXVI

QUANTITY OF STREET CLEANINGS, BY MONTHS

CUBIC YARDS PER CAPITA PER MONTH

City	Jan.	Feb.	Mar.	April	May	June
Cincinnati	.0191	.0191	.0349	.0339	.0316	.0338
Cleveland	.0102	.0043	.0250	.0550	.0288	.0246
Columbus	.0000	.0042	.0148	.0276	.0329	.0370

City	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Cincinnati	.0314	.0347	.0337	.0383	.0321	.0173	.3600
Cleveland	.0315	.0292	.0291	.0276	.0294	.0131	.3078
Columbus	.0305	.0406	.0315	.0386	.0366	.0041	.3284

as fruit skins, pieces of paper, matches, etc. Also great quantities of leaves in the fall on streets provided with shade trees. The increasing use of automobiles has slightly reduced the amount of horse droppings, but has added oil to the extent of about 2 per cent of the total in some cases. Rubber tires have reduced the amount of abraded stone. The use of litter barrels and enforcement of the law would greatly reduce the amount of rubbish, earth dropped from carts, store sweepings and other matters swept up in the streets of most cities.

In large cities about one-fifth to one-third of street sweepings is organic matter, about one-third to one-half is moisture and the remainder is non-combustible; but this would vary greatly between asphalt and macadam streets, for instance. The weight of street sweepings varies generally between $\frac{3}{4}$ ton and 1 ton per cu. yd. The calorific values of the sweepings of Cincinnati, Cleveland and Dayton were 1445, 2133 and 1680 heat units respectively.

A thorough and extended study of Chicago's refuse made by the Bureau of Streets gave the following figures: Ashes and rubbish in 1912, average amount per capita per year for each of 35 wards varied from a maximum of 1176 lbs. to a minimum of 270 lbs.; or from 3240 lbs. to 743 lbs. per 1000 population per day, the average being 1575 lbs. per 1000 population per day. The garbage, by wards, varied from 160.8 lbs. per capita per year to 54.5 lbs., averaging 108.9 lbs.; or from 518 lbs. to 177.8 lbs. per 1000 population per day, averaging 336 lbs. A cubic foot of ashes and rubbish averaged 31.5 lbs. in weight. Garbage varied in the different wards between 45.7 lbs. and 33.5 lbs. per cu. ft., averaging 39.4 lbs.

The per capita production for Chicago is lower than that found in other cities, due to the fact that the population contains a large foreign element, the large vacant areas invite the disposal of garbage by the householder on the premises, and the garbage produced in hotels and restaurants is collected by private cartmen.

Other Matters. The number of dead animals which must

be disposed of in a city of even moderate size is considerable. St. Paul in one year collected 958 dead horses and cows and 2187 small animals; Savannah, Ga., 94 horses and cows and 1770 small animals; Columbus, O., 2366 animals, large and small.

Trade wastes include slaughter house refuse (called offal), that from fish and meat markets, shells of bivalves, fruit, scrap tin, sawdust, leather, cloth trimmings and numerous matters, animal, vegetable and mineral. Many if not most cities do not collect these, but require the tradesmen to attend to the disposal of them.

Snow may amount to enormous volumes, and no city ever removes all of it. A 12-in. fall on a block 400 ft. long of a 60-ft. street would amount to 200 large wagon loads, if not compressed. Snow when melted occupies only one-seventh to one-fifteenth as much volume, and may pack to one-fourth that of loose, light snow freshly fallen. It weighs about 115 to 250 lbs. per cu. yd. After standing on a street for a few days it has mixed with it all the materials classed as street sweepings.

Sewage will not be considered in this discussion. See the several excellent books on sewage disposal.

Art. 29. Dumping Refuse

By dumping is meant depositing on land without further attention other than the burning of papers and other easily combustible matters. (Refuse is sometimes dumped into streams or other bodies of water also.) Land which would be improved by raising is chosen where possible.

Garbage unmixed with other materials should never be dumped, for it will putrefy, cause a most intolerable nuisance, attract dogs, rats and other animals, breed flies, and the fill so made will not for years, if ever, be fit to build upon. If great care is used to mix ashes or soil with the garbage, use a deodorant or disinfectant freely, and spread the garbage in thin layers, tolerable results may be secured. Chicago, in 1913, as an emergency measure, soaked garbage for twelve hours in vats filled with water containing $\frac{1}{2}$ per cent of hydrochloric acid and $\frac{1}{2}$ per

cent sulphuric acid to delay putrefaction. The garbage was then dumped on low land, spread to a layer 1 ft. thick, covered with a layer of ashes 18 to 24 in. thick, which later was covered with other layers of garbage similarly treated, until a depth of 25 ft. was reached, which finally settled to 16 ft. No offense was noticeable a year later. This cost little if any less than some other methods of treatment, and the method needs careful watching to insure proper spreading and covering.

Ashes can be dumped with no offense other than the blowing about of dust, and make excellent fill for streets or for building lots. In most cities this is the best use that can be made of them.

Rubbish is generally such a heterogeneous mixture that it is difficult to generalize concerning it, but most of it can be dumped without any objectionable features from a sanitary point of view. Tin cans or other objects which have held food materials are objectionable in large numbers, but an occasional one need not be. It is better to include such cans with ashes, which will fill the can and very largely prevent the contents from decaying, attracting flies, rats and other animals. Furniture, boxes, etc., if not broken up, will permit the fill to settle continuously for years as the wood decays. Scrap tin offers the same objection and also is almost impossible to dig through for cellars, street trenches and other excavations. Paper is sure to be blown about the neighborhood and be an intolerable nuisance unless at once covered with dirt, ashes, etc. Paper, wood, cloth and other combustible matters, if lighted, may communicate the fire to similar matter under the surface, which will smoulder for a long time. Such smouldering fires have been known to continue for years even, especially where there is unburned coal in the fill, and defy all practicable efforts to extinguish it. Such combustable matters should generally be burned on top of the pile as received, or sold or given away for fuel, and not left permanently in the fill. Almost the only danger from a sanitary point of view is connected with bedding and clothing used by those having contagious diseases, and the board of health and physicians should see that none such ever reaches a public dump.

FIG. 97.—Refuse Dump and Electric Truck, Boston, Mass.

Street sweepings are perhaps better dumped than disposed of in any other way. As only about 20 per cent is organic matter, there is practically no danger from putrefaction. As the material is very fine dust, however, it is apt to create a nuisance by blowing about. It also continues to compact somewhat with time, causing the fill to settle.

Manure is almost entirely organic matter, decomposes quite readily in the presence of moisture, and is generally unsuitable for filling.

It is evident that almost any dumping is apt to create a nuisance unless some care be taken. But if the grounds be surrounded by a board fence, a close, high hedge or other wind break and confiner of blowing paper and concealer of unattractive sights; if no one be admitted therein but city's or contractor's employes; and if all paper, excelsior and other light material be burned, boxes and furniture be broken up, and any chance putrescible matter be scattered and mixed with ashes or dirt, there need be little objection to this method, except to having the material hauled through the adjacent streets. Even the garbage of a town or small city can be so disposed of unobjectionably if spread in thin layers and mixed or covered with ashes and fine rubbish. This can be done by an employee constantly on the ground; or each driver may be required to burn, break up, spread, etc., his load as soon as dumped. In many cases a license is given granting to one man exclusive right to sort over the rubbish and remove from it wood, bottles, metals, papers, old shoes and rubbers and other salable materials, in return for which he keeps the dump in shape free of charge. In the case of large cities such a privilege is sometimes sold for many thousand dollars.

Dumping, even if a man is employed to look after the dump, is much the cheapest method of disposing; except in the case of large cities where sorting over refuse and extracting grease and tankage from garbage yield a revenue, and where land for dumping is not available near the city. By no means the least advantage is the short haul possible in many towns, where there is low

land, streets that need raising, tidal meadows, old quarries or other places scattered in or near the built-up section, where filling increases the value; while most other methods of disposal call for hauling all the refuse to some one point, and this very frequently an inaccessible one.

But if streets are to be located on such a fill or buildings placed on it, the greatest care must be used to see that no future settlement is possible. All paper, wood or other organic matter must be burned or excluded; all large matters broken up and scattered so no pockets can be formed. In fact, no foundation for a building is safe on any *rubbish* fill, but should be carried down to original soil; although ashes may serve as foundation for an ordinary house.

Dumping into water is almost sure to create a nuisance somewhere. If into a river, the lands below are apt to receive, stranded along the shore, quantities of vegetable matters, and any water supplies drawn from the river will be polluted. Even if dumped in the ocean, winds blowing toward shore will carry floating matters there, and a large part of garbage matters will float for a long time. Two or three California cities carry their garbage 20 miles from shore into the Pacific. One or two others dump theirs from cliffs into the ocean where there are no settlements or resorts. New York abandoned the practice of dumping garbage at sea years ago because the matter was carried to the Long Island and New Jersey beaches. A small town could not afford to carry garbage to sea; and no other water dumping is defensible, and this is not often so.

Art. 30. Burying and Use as Fertilizer

Garbage, while offering more serious difficulties in connection with disposal than any other class of refuse, also contains the most valuable properties of any. A considerable percentage of grease is found in most garbage (varying with the use and waste of meats by the citizens), which is undesirable in a fer-

tilizer, but most of the other ingredients have a fertilizing value. Ashes have a slight value as fertilizer and also improve the porosity of a heavy soil. Rubbish has no value in the soil. Street sweepings have a low fertilizing value, the mineral oils contributed by automobiles being actually deleterious; but the large amount of fine mineral matter improves the physical condition of the soil. Manure is, of course, the best of fertilizers. Night soil is beneficial if thoroughly mixed with the soil or other materials (ashes, street sweepings, etc.). The bodies of small animals may be classed with garbage. Dead animals of large size may ultimately improve the fertility of the soil, but their burial is at first objectionable. Trade wastes may or may not be beneficial to the soil, depending upon their character. In general they are not.

Garbage, if applied to the soil directly, must be covered with soil or ashes to prevent nuisance from flies and animals, to prevent odors of putrefaction, and to keep it in a state of moisture which allows continuous but slow decomposition. If no soil or ashes is being dumped at this point, this covering is effected by plowing or digging trenches 18 to 30 in. deep, spreading the garbage in these 6 to 12 in. deep and covering it with not less than 12 nor more than 18 in. of soil. The soil used for cover should be sandy, or else finely broken up, and should be spread over all garbage as soon as it is placed in the trench. This permits air to reach the garbage, but no flies or sun. Probably the cheapest plan is to dig one long trench and, as the garbage is deposited in this, cover it with soil dug from a parallel trench about 2 ft. away; the second trench to be filled from a third, and so on. The same field can be used again in the same way in from three to six or eight years, depending upon nature of soil, climate, vegetation grown, etc. This method is especially beneficial to a sterile or acid soil.

Street sweepings need not be buried in this way, but may be simply spread on the surface and plowed under.

The most common disposal of night soil is as a fertilizer in one way or another. It is sometimes simply thrown on the soil

and plowed under. This is objectionable in many ways, however, and may cause typhoid through fly transportation, and it is better to mix it with ashes, dry clay or other absorbent of moisture, which will partly dry it so it can be pulverized or more easily distributed without nuisance; then bury it by spreading in furrows and plowing the ridges over onto it.

Art. 31. Feeding to Animals

Garbage is the only waste matter (other than market wastes) which can be fed to animals. Its value for this depends to some extent upon the habits of the people as to food and wastefulness; also whether glass, crockery, oyster shells and other foreign, inedible matters are mixed with it. It should be fresh, and no garbage which has begun to sour should be used as food for any animals. When fresh and containing no glass or poisonous matters, it has high food value.

Hogs are the animals most commonly fed. Feeding garbage to cows is forbidden by law in Colorado, Massachusetts, New Jersey and several other states and cities, as it is generally admitted that the milk from cows so fed is of inferior quality and that cattle do not thrive on garbage. Feeding to swine garbage not more than two days old in summer, or four or five days in winter, will produce good pork, especially if corn be used for the final fattening. In scores of towns and several large cities the garbage is used in this way. In some cases the users collect the garbage for nothing, but ordinarily they charge a small sum for collecting, or else the town collects and charges them for the garbage. Grand Rapids, Mich., has since 1907 sold its garbage to a hog-raising firm, delivering it on cars in the city. Los Angeles, Cal., has a standing offer of $2.00 a ton for it. A number of Massachusetts towns sell it to farmers, receiving $1\frac{1}{2}$ to 6 cents per capita per year for it.

Chickens will eat the solid parts of some kinds of garbage, but the amounts fed to fowls is inconsiderable.

Garbage is treated and made into foods for animals, as described in the following article.

Art. 32. Reduction

Reduction of garbage consists essentially in extracting the grease, removing the water and preparing the dried residue for use as fertilizer or animal food. This residue is called tankage. The various processes for accomplishing this are patented, and are differentiated by the methods of separating the grease and water from the solids and of preventing the escape of odors during the cooking and drying. They are the Merz system, the Simonin, the Holthaus, the Arnold, and two or three others.

In the *Merz* process the liquid is first drained off by gravity into the sewer and the solid matter is then culled of rags, bones, metals, glass and other foreign matters, which are sold. It is then dumped into jacketed cylindrical dryers, each holding about three tons, where it is stirred by revolving arms for six hours while being dried by hot air. It is then a greasy, dark brown, comminuted substance with little odor, which is placed in closed tanks called extractors, where naphtha is allowed to percolate through it to dissolve out the grease. This solution is drawn off, the naphtha driven off as vapor (to be condensed and used again), and the grease barreled for sale. The dry residue in the extractors is ground, sifted, and sold for fertilizer filler or animal food. The grease is of a dark brown or green color, has a garbage odor, and is not in very great demand. If there were many utilization plants in operation it probably would be almost impossible to dispose of the most of the grease.

In the *Simonin* process the garbage is not dried before the grease extraction, but the wet garbage and naphtha are heated by steam coils in extractors. After dissolving out the grease, the naphtha, together with the water, are evaporated and pass into a condenser to be liquefied and thence to a separator, where the naphtha is recovered. The grease remains at the bottom

of the extractor, from which it is drawn, the remaining naphtha is evaporated off, and the grease barreled for sale. About forty-eight hours are required for the entire operation.

In the *Holthaus* system the garbage is cooked by steam in digesters, whence it falls into a press where the water and grease are pressed out into a separating tank, where the grease is skimmed off and barreled. The tankage is dried, ground and screened. This system is especially inoffensive, as all the apparatus is tightly closed, all gases are passed through a fire and all water vapors condensed.

The *Arnold* process is apparently the simplest and least expensive, and is used in New York, Philadelphia, Boston and several other cities. The rubbish is first picked out of the garbage and this is then cooked as in the Holthaus system, and the liquid pressed out by passing the cooked garbage through a continuously rolling press. The grease is then separated from the water by gravity. As conducted, this process is generally quite offensive.

Until 1910 no reduction plant had been owned or operated by a municipality and no information was made public concerning the cost or profits of the process. Different cities were paying from 60 cents to $2.00 per ton to reduction companies for disposing of their garbage. In July, 1910, Columbus, O., began operating a reduction plant built after plans of I. S. Osborn. This has been improved from time to time and is (1915) perhaps the best of its type in use. In brief the operation consists of discharging the garbage onto a floor from which the water of the garbage drains off to the sewer. Large pieces of rubbish are sorted out and the garbage is carried by conveyor to eight digesters, each of 10 tons capacity. Steam enters these at the bottom at 60-lb. pressure, cooking the garbage, and steam and gases leave through a pipe at the top, are condensed by jet condensers, any uncondensed gases passing through the boiler fires. The cooked garbage then passes through a roller press, which presses out the free liquor and grease, which flow to catch basins, from which they are pumped to six separating tanks.

Here the grease rises to the top of the liquor and is drained off to treating tanks, where the grease is stored for shipment in tank cars. The liquor carries some solids in suspension, known as muck and silt, which are drawn off into a muck tank. The solids from this are pressed, the liquor flowing to the catch basins, the solids being added to those from the large press. The tank water is drawn off into a large tank where more grease rises to the surface and is drawn off. The water from the tanks is then evaporated to recover solids in solution, producing a syrup which is added to the tankage.

The solid matter from the press is dried in a revolving direct-heat dryer and then is carried to a "percolator," where gasoline is applied to it, which dissolves out the grease. Gasoline and grease are then drawn into distilling tanks, the gasoline is driven off as vapor by steam heat, condensed and used again. (Part of the gasoline is not recovered, the loss averaging about 10 cents worth per ton of garbage.) This process is repeated three or four times. Live steam is then passed through the tankage to drive out the gasoline, the tankage is screened, mixed with the syrup above referred to, again dried, ground and screened through a ten-mesh screen, when it is ready for shipment. In 1914 Columbus received $52,672 for the grease so recovered, $12,988 for tankage and $1,032 for hides. It recovered 54.87 lbs. of grease and 162.1 lbs. of tankage per ton of garbage. It received $4.325 per 100 lbs. for the grease and $7.41 per ton for the tankage. The cost of operation was $40,221, and interest at 4 per cent and depreciation at 5 per cent amounted to $21,320, leaving a net profit of over $5000. The plant cost about $112,000 and the buildings, track, scales, etc., and engineering $125,000 more.

The latest system of garbage reduction is that known as the "*Cobwell*." The first permanent plant using this began operation in Los Angeles in 1915. It was built and is operated by a private company, which pays the city 51 cents a ton for all garbage delivered at the plant and for the water required to operate the plant. (This latter innocent-looking clause calls for

water worth 77 cents per ton of garbage at the regular water rates.) In this system the garbage is sorted and conveyed to steam-jacketed cylinders, each taking a charge of $3\frac{1}{2}$ tons of garbage. A petroleum product similar to naphtha is added, and the whole is stirred mechanically, while live steam at 85-lb. pressure is admitted to the jacketed walls and bottoms. Since water is vaporized at a lower temperature when combined with a solvent having a low boiling point, the heat causes both solvent and water to pass off through a large vapor line. They are then condensed and separated by gravity, the clear water flowing to the sewer and the solvent returning to the reducer; the operation being continued until all the water has been driven off.

The grease is by this time all free and dissolved in the solvent. Solvent and grease are drained to a still, where the solvent is driven off and the grease recovered. The material left in the reducer is tankage. This operation requires ten to sixteen hours. The tankage is then screened and is ready for sale. One ton of green garbage is said to produce 600 lbs. of tankage and 85 lbs. of grease, or 60 per cent more grease and 3.7 times as much tankage as the Columbus plant. (This must be due to the different natures of the garbage, since the only losses which could occur in the Columbus plant are the water and other materials which could pass off as vapor, and there could hardly be 440 lbs. per ton more of volatile matter [other than water] in one garbage than in the other.) The tankage is being sold as food for live stock. The loss of solvent is said to be 3 gallons (worth 33 cents) per ton of garbage. Power for operating the plant is obtained by burning rubbish.

The reduction plants in existence are given in the accompanying table. There are believed to be none outside of the United States, as other peoples throw away too little valuable food matter to make the process profitable.

Dead animals are treated in a manner similar to reduction but simpler, called "rendering." The carcasses are skinned if the hides are of any value, and are cut up and cooked in steam,

TABLE XXVIII

GARBAGE REDUCTION PLANTS IN THE UNITED STATES

(Prepared by Wm. F. Morse, Consulting Sanitary Engineer, in 1914, and supplemented by recent data by the author.)

City.	Owner.	Capacity, tons per day.	Paid per year by city for disposal.	When built.	Remarks.
Pittsburgh	American Reduction Co	.....	.....	1885	Continuous contract 1914.
Indianapolis	Indianapolis Sanitary Reduction Co.	.....	.....	1898	Continuous contract; new company in 1914.
Atlantic City	Atlantic Products Co.	.....	$20,000	1903	Continuous contract.*
Cincinnati	Cincinnati Reduction Co.	.....	.....	1903	New organization 1913.
Utica	Stiepenbeck Co.	.....	.....	1904	Contract to private company.
New Bedford	American Extractor Co.	60	.....	1905	Cobwell system in 1914.
Washington, D. C.	Washington Fertilizer Co.	.....	51,600	1905	Renewal of contract to 1915.
Wilmington, Del.	Wilmington Reduction Co	.....	.....	1906	Private terms.
York, Pa.	York Sanitary Reduction Co	.....	.....	1906	Private terms.
Reading, Pa.	Reading Sanitary Reduction Co.	.....	.....	1906	Changed to mun. incinerator in 1914.
Chicago	Chicago Reduction Co.	.....	.....	1906	Plant taken by city in 1914.
St. Louis	St. Louis Standard Reduction Co	.....	.....	1907	New plant in 1913.
Rochester	Genesee Reduction Co.	240	77,500	1907	
Philadelphia	Sanitary Utilization Co	.....	.....	1894 1908	Company held contract for successive years.
	Pennsylvania Reduction Co.	.....	323,583	1908 1914	Contract for collection and disposal.
Baltimore	Southern Products Co	.....	25,000	1908	Additional $2000 after first year. Continued contract.
Syracuse	Syracuse Reduction Co.	.....	13,975	1908	Continuous contract.
Boston	Boston Sanitary & Developing Co	.....	.....	1912	
Bridgeport	C. A. Fisher.	.....	.....	1912	
Springfield, Mass.	Merz Reduction Co.	.....	.....	1913	
New York	Sanitary Utilization Co.	2000	.....	1895	New contract in 1916; plant not yet erected.
Los Angeles	Pacific Reduction Co.	175	.....	1915	Company pay city 51c. per ton.
Municipal Plants					
Cleveland, O.	City.	200	.....	1905	Bought plant of private company.
Columbus, O.	City.	160	.....	1908	
Schenectady, N. Y.	City.	100	.....	1913	
Chicago	City.	800	.....	1906	Taken by city and rebuilt in 1914. Some garbage incinerated.
Akron	City.	40	.....	1914	
Detroit	City.	450	.....	1915	
Dayton	City.	125	.....	1916	

* New contract with Farmers' Supply and Production Co. begins in 1916.

TABLE XXVIIIA

GARBAGE REDUCTION PLANTS

INFORMATION COLLECTED BY MUNICIPAL JOURNAL IN NOVEMBER, 1915

City.	Population.	Designer or builder.	Privately or municipally operated.	Nominal capacity, tons per 24 hours.	Year built.	Cost of original construction.	Cost of extension.	Distance of plant from center of city.
Los Angeles, Cal.	320,000	C. O. Bartlet Snow	Private	300	1915	$100,000	.....	3 miles
Bridgeport, Conn.	103,000	.....	Private	60	1910	.....	.....	.....
Washington, D. C.	353,300*	.....	Private	.....	.....	.....	.....	40 miles
Chicago, Ill.	2,200,000	.....	Municipal	800	1914	725,000	.....	
Boston, Mass.	670,000	.....	Private					
Detroit, Mich.	475,000	Detroit Red. Co	Private					
St. Louis, Mo.	690,000	.....	Private	400	1913	300,000		
Rochester, N. Y.	250,000	.....	Private					
Schenectady, N. Y.	75,000	.....	Municipal	100	1914	110,000	.....	½ mile†
Syracuse, N. Y.	140,000	.....	Private	.....	.....	.....	.....	1½ miles
Utica, N. Y.	75,000	.....	Private	100				
Cleveland, O.	780,000	.....	Municipal	200	1905	64,000	208,000	8 miles
Columbus, O.	210,000	T. S. Osborn	Municipal	160	1910	200,000	36,000	4½ miles
Dayton, O.	130,000	.....	Municipal	125	1915	55,000	.....	2 miles
Philadelphia, Pa.	1,550,000	.....	Private	500				
Pittsburgh, Pa.	533,000	.....	Private					

* Only part of garbage reduced.

† From nearest buildings.

the water and grease are pressed out and the solid part is dried and ground. Where the garbage is utilized by reduction, dead animals are generally added to it after removing the hides and bones.

Reduction or rendering gives rise to an intolerable nuisance from the odors, principally those from the cooking, unless great care and considerable expense are incurred to avoid it. Even then there are probably no plants which have run for any length of time without at some time giving off objectionable odors noticeable for several hundred feet from the plant.

Art. 33. Incineration

Incineration, or reducing to ashes by fire, is the most certain way of finally rendering harmless and unobjectionable all kinds of animal and vegetable matter. Garbage, ashes, rubbish, street sweepings, trade wastes, dead animals, manure, night soil, and in some cases sewage sludge, all are burned in incinerators. The plant required is expensive, but not so expensive as that used for reduction, nor is the operation so costly; but there are no products but clinker or ashes, and heat. Both of these theoretically have value, and in some cases this is realized, but in most it is not. It is especially suitable for destroying rubbish (after the salable matter has been sorted out). It destroys any disease germs which may exist in bedding, old clothing, diseased animals, etc.

Incineration can be so conducted as to create no nuisance, plants being located in the midst of residence districts in some cities; but to insure this, all gases must be burned at a temperature not lower than 1400° Fahr. (theoretically, 1200° is necessary for ignition of hydrocarbons, but practically 1400 to 2000 is necessary as the average of the combustion chamber), and the wet garbage and other materials must be burned, not cooked, and all vapors and gases given off must be raised to the temperature named before reaching the chimney. Dry kitchen gar-

bage will burn of itself, as will street sweepings, and most rubbish is quite inflammable. But if the material, whether garbage, manure or other organic matter, contains more than 35 or 40 per cent of moisture, it must be dried before it will burn. Moreover, any of the refuse matters except rubbish require considerable heat to start combustion.

If garbage and dead animals alone are to be incinerated, fuel is necessary in the furnace, of whatever kind, although some furnaces require five or ten times as much fuel as others. Before burning such material, the free water should be drained off and either run to a sewer or evaporated. (Evaporation of water is an expensive proceeding.) The moisture remaining in the material is then evaporated, generally by the heat from the furnace, and the material is burned. The evaporation of the water, the drying and the burning, all produce offensive vapors and gases, and these must be passed through another hot fire, or a hot part of the main fire, to effect their combustion. All parts of the refuse must be entirely oxidized and no unburned matter be allowed to reach the ash pit.

Several incinerators have been designed to meet these requirements. Some of the earlier American designs used two fuel fires; the heat from one being passed over or under the refuse, or both (owing to its nature, it is almost impossible to pass the hot air *through* the garbage), and the hot air and gases then passed over another fire at or near the base of the chimney. The keeping of the heavy, sodden mass spread thin so that all parts of it will be burned, the proper feeding of fresh charges so as not to deaden the fire, the stoking without introducing cold air to chill the furnace and the burning refuse, and the removal of the material when, but not until, it is entirely incinerated, all require skill in construction and in operation not called for in ordinary furnace practice. The high temperatures, the feeding of wet garbage, and the fact that no comparatively cool air passes up through the grate, make the construction of a durable grate a difficult matter. Some use grates made of parallel narrow flat arches of fire brick; others use heavy cast-iron, which must be

renewed frequently; some use hollow cast-iron through which air circulates, and others use wrought iron tubes through

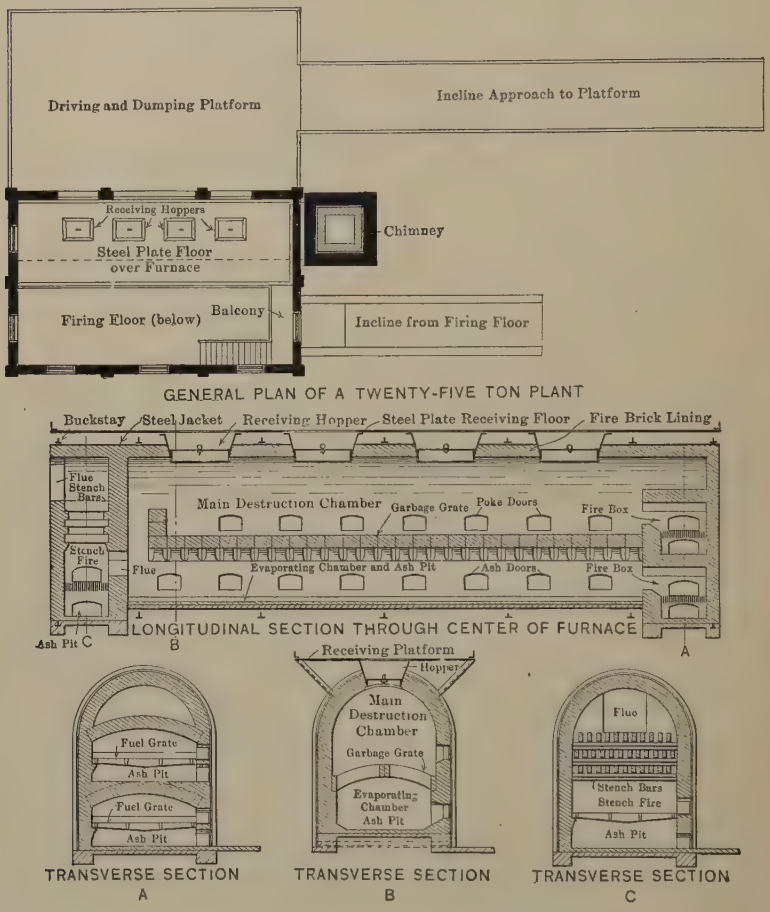


FIG. 98.—Plan and Section of a Twenty-five Ton Dixon Garbage Furnace.

which water circulates to keep the temperature of them low. The walls and top of the furnace are generally lined with fire brick.

Venable divides crematories into five classes: (1) In which

refuse is burned on a grate without preliminary drying, suitable for dry combustible wastes but not for garbage. (2) In which

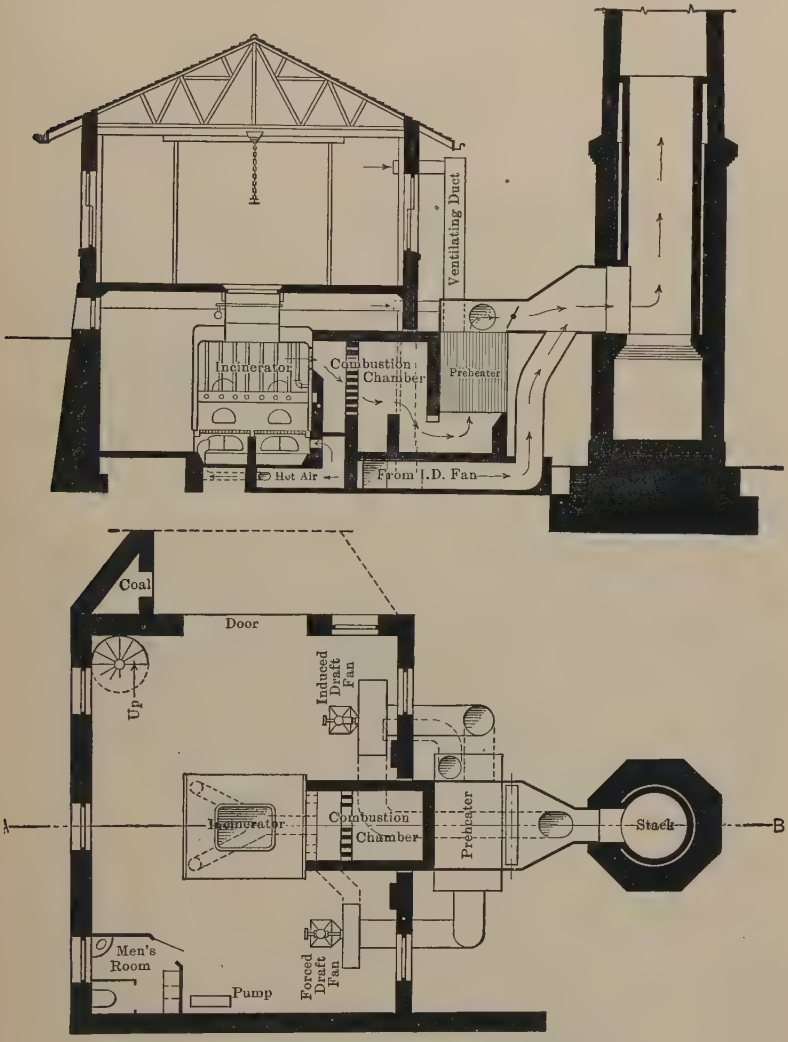


FIG. 99.—Plan and Section of Decarie Incinerator.

refuse is burned on a grate with little preliminary drying on an adjoining hearth, suitable especially for mixed garbage, ashes

and rubbish and generally requiring forced draught. (3) In which garbage is burned on a hearth or grate by subjecting it to intense heat from fuel fires on other grates—the so-called American type, suitable for burning wet garbage, unmixed with dry refuse. (4) In which garbage is first extensively dried on a hearth or grate and then stoked to another grate to be burned as fuel. (5) In which gases of combustion from burning garbage in one cell are passed through other cells to dry garbage therein, which in turn is burned.

Class No. 1 is used in several cities for burning rubbish—paper, old furniture, boxes and other inflammable material. Class 2 is the English style of furnace, of which several have been built in this country since about 1908. A boiler is generally combined with this furnace, in which steam is raised by the high temperature obtained by forced draught. Class 3 is most common in this country, although there are quite a number of Class 4. There are few if any of Class 5 now in use. In Classes 3 and 4 high temperature of the gases must be obtained to prevent odors, and after the odor-bearing matters have been destroyed the heat can be used to raise steam in a boiler if it is not needed to create draught in the chimney. Only a few furnaces of this class are provided with boilers.

The amount of steam which can be raised by burning mixed refuse should theoretically be sufficient to pay the operating expenses of the incinerator and possibly part of the fixed charges. Several plants use the steam to advantage but none approximate the theoretical return in actual income obtained, for several reasons. The class of labor hired by the city seldom has the skill or interest to stoke the fires properly, this being difficult and most arduous work. The refuse is brought in widely varying mixtures of garbage and combustible matters, and cannot well be sorted out and re-mixed to advantage, so that the steam available varies unforseeably and uncontrollably. As a result, it is difficult to find a market for the steam, or a municipal use for it. One city heats a hospital, another operates a sewage pumping plant, another an electric plant. The most favorable

condition probably is where the plant is near a municipal plant which use several times as much steam as the incinerator can furnish, and uses coal fires (or gas or fuel oil) as its main source of heat for steam raising, using the incinerator steam as an auxiliary.

The ashes from most plants are not sufficiently hard or vitreous to be used for concrete or cinder foundations, the exceptions

FIG. 100.—Dixon Garbage Incinerator, Sewickley, Pa.

being the furnaces of Class 2, which use forced draught. Even these may not yield clinker uniformly hard; and very few cities have made any use of the clinker. Theoretically the ash has some value as a fertilizer, but not enough to pay for marketing it.

Cost. The English style of furnace costs $750 to $1250 per ton capacity.

The American style of furnace costs from $250 to $700 per

ton capacity, depending upon the make, quality of materials used, size, and amount spent on the foundations and enclosing building. In general the cheaper furnaces are made of less durable construction, and with buildings of corrugated iron or other cheap construction. Some very good plants have been bought for from $300 to $500 per ton, however. The capacities vary from 10 tons up, with a few of 7 or 8 tons capacity, these being the capacities if run continuously twenty-four hours a day. To a large degree the capacity is that of the garbage alone. If rubbish is burned with the garbage in amounts equal to half that of the garbage, it burns quickly and hastens the burning of the garbage. In other words, a furnace having a capacity of 10 tons of wet garbage can be made to burn 5 tons of additional refuse.

The American style of furnace, using fuel on separate grates, is generally operated in one shift of eight to twelve hours per day. In 1915, of 31 such furnaces, 21 operated one shift, 8 two shifts and 2 three shifts. The English style of furnace, (often called "destructor") however is best operated continuously, as only in this way can be avoided the use of considerable amounts of fuel for starting the fire each day. The mixed refuse can be stored during the day for burning at night without creating a nuisance; while the garbage alone that is fed to the American type cannot be stored so well. With the small furnaces, moreover, three shifts would be too expensive, since one man in eight or ten hours can burn as much as four or five tons of garbage.

The destructors require no fuel except the refuse, where there is the usual amount of this collected. The cost of fuel for the American furnace generally varies from 10 to 30 cents per ton, although some run as low as 7 cents and a few as high as 60 cents. The cost of labor varies generally from 25 cents to 80 cents a ton. Repairs and renewals of grate bars may bring the total for some furnaces up to $2.00 a ton, but it is generally under $1.00. The total cost for the American furnace, including 10 per cent of the cost for interest and depreciation, will run from

45 cents to $2.50 per ton; that of the destructor about $1.65 to $2.00 per ton.

The life of a furnace depends so much on the character of construction, care taken in firing and upkeep, and other conditions, that no general approximation even can be made. But well designed and constructed American furnaces are now in operation which were built fifteen or twenty years ago. On the other hand, one or two furnaces have gone to pieces inside of two years. No destructor, we believe, has yet reached its limit of useful life.

Purchasing Incinerators. In purchasing an incinerator, definite requirements should be stated and provision made for a test of at least a week's duration to determine whether they have been met. It is still better to require the builder to run the incinerator for a month, the city paying all expenses for labor, fuel, etc., but assuming no responsibility and not accepting the plant until after, at the end of that time, a twenty-four-hour or forty-eight-hour run is made under the supervision of a competent representative of the city, during which test all weights and analyses of refuse and fuel burned, temperatures of gases, and other determinations are made necessary to test the efficiency and sufficiency of the plant.

The contract should guarantee that the incinerator will burn a certain amount of garbage (or of refuse, as the case may be) in eight, twelve or twenty-four hours, specifying whether starting cold or at full heat; the amount of coal (or wood or gas) which will be required; the amount of labor necessary about the plant; that the temperature will at no time fall below 1500° in any part of the combustion chamber; that there will be no odors given off from the plant; and that the ashes shall contain no matter not thoroughly reduced to ash or clinker. The kind and condition of material to be fed to the incinerator must be specified as definitely as possible, this being governed by the nature of the refuse which will be burned in service—whether garbage alone, or with ashes or rubbish. The percentage of household garbage, of water in the same, of fine ashes, of unburned coal

in the ashes, of wood in the form of rubbish, which is to go to make up the material to be burned in the test should be specified.

It is commonly difficult to collect sufficient refuse to test the capacity of a new incinerator, for the collection service may not be fully organized, but especially because the furnace is generally of a capacity to meet requirements of a few years later. Refuse and ashes can be stored for some days ahead of the test, but garbage cannot well be, as it will putrefy and will also settle and squeeze out the free water and change its consistency. This difficulty may be met by arranging to receive garbage from one or two neighboring towns, bringing it by railroad if necessary. Several cities, having failed to foresee this difficulty until the day of the test arrived, have contented themselves with a makeshift test which proved nothing, only to learn later that it would, if properly made, have proved the insufficiency of the plant.

Decision as to whether it is desirable that rubbish be mixed with the garbage to serve as fuel, or coal or other fuel be used, should be made by some one competent to judge after careful consideration of the character and amount of garbage and of rubbish which will be collected, location of plant as affecting length of haul and offense caused to residents, other uses to which rubbish could be put, cost of coal delivered at the plant and other considerations of economy.

In many plants the greatest cause of offense is not the furnace itself, but the storing of garbage and the passing of garbage carts through the streets. The latter is discussed in the next chapter. Storage can be avoided by having a furnace and fire sufficiently large to burn the garbage as it is delivered at the plant, but it can be made inoffensive by proper precautions and equipment.

Art. 34. Selling Sorted Refuse

The salable materials in refuse include newspapers, mixed papers, manila paper, charcoal sacks, flour bags, rags, tin cans, iron, and bottles. The different classes of papers and the rags are baled separately; tin cans are sold loose to detinning com-

panies or unsoldered, flattened and nailing caps stamped from them. The bottles and scrap iron are sold to dealers in these materials, or the bottles to the breweries, etc., from which they originated, and the iron to foundries or others. Old shoes are sold for burnishing and polishing castings or to be fixed up and sold for further use as cheap shoes.

In 1914 the Street Cleaning Department of Cleveland, O., sold the following materials at the prices given:

TABLE XXIX

SALABLE MATERIAL COLLECTED IN CLEVELAND, O., IN 1914

3,055	bottles	$17.62
47,763	bottles, at ½c each	238.86
71,732	pounds bottles, at $5 per ton	179.33
13	syphon bottles, at 10c each	1.30
238	jugs, at 1c each	2.38
530	jugs, at ½c each	2.65
41,706	milk bottles, at ½c each	208.53
10	seltzer bottles, at 10c each	1.00
28,208	beer and pop bottles, at ½c each	141.04
3,025	peroxide bottles, at ½c each	15.13
220	Coca Cola bottles, at ¾c each	1.65
1,000	catsup bottles, at ½c each	5.00
	Miscellaneous bottles	79.09
200,945	pounds broken glass	461.89
2,199	barrels	226.44
4,074,000	pounds manure, at 80c per ton	1,629.60
67	loads of manure, at 40c per load	26.80
2,880	pounds copper, at 11½c per lb	331.22
1,012	pounds mixed rubber, at 4c per lb	40.48
9,306	pounds rubber hose, at ¼c per lb	23.29
3,050	pounds zinc, at 3c pr lb	91.50
506	pounds old alarm clock, at ¾c per lb	3.79
78	hot water tanks, at 5c each	3.90
	Other miscellaneous metals	39.64
12,865	pounds rags, at $12 per ton	77.19
1,910	pounds rags, at $13 per ton	12.41
33,875	pounds rags, at $18 per ton	304.88
258,663	pounds rags, at $18.50 per ton	2,392.62
20,560	pounds scrap iron, at $7 per ton	71.96
98,044	pounds scrap iron, at $5.60 per ton	274.53
16,111	pounds scrap iron (pier) at $8 per ton	67.00
23,110	pounds scrap iron (pier) at $8.10 per ton	95.90
105,754	pounds tin cans, at $4.50 per ton	237.95
925,312	pounds waste paper, at $5.60 per ton	2,559.47
3,982,594	pounds waste paper, at $5.75 per ton	11,449.96

Buffalo in 1911 obtained the following prices for material sorted from rubbish, the total amount so received being $39,176,

about one-third of the rubbish being utilized: Newspapers, 42 cents per 100 lbs.; mixed papers, 32 cents; manila paper, 60 cents; charcoal sacks, 75 cents per 100 lbs.; flour bags, $1.75 per 100 lbs.; rags, 50 cents per 100 lbs.; beer bottles, 1 cent each; mixed bottles, 40 cents per hundred; water bottles, 1 and 3 cents each; old shoes, $6.50 per ton; tin cans, $4.50 per ton; tin cans when made into nailing caps, $65 per ton;

All the sorting in Buffalo was done by girls who received $1 for eight hours' work, the yearly payroll exceeding $25,000. Other expenses were about $10,000, so that even at that low wage there was very little profit.

Art. 35. Separation of Refuse; Receptacles

Refuse is removed from residences and business places to the points of disposal by city employees in some cases, by private parties in contract with the city in others, while in many small cities and villages each householder must arrange for the removal of his own. In 1915, of 168 cities investigated by *Municipal Journal*, city employees made the collection in 87; in 9 the city collected part (usually ashes and rubbish) and the remainder was collected by contract; in 9 there was no definite arrangement, and in 63 all which was removed was by contract, although in several cities only garbage, or garbage and ashes, were removed. Of these cities, 9 did not provide for removing garbage; 64 did not remove ashes; 80 did not remove rubbish; 130 did not remove trade or industrial refuse.

Separation. The household is generally required to separate the refuse into two or three classes, keeping each in a separate receptacle. The classification will generally depend upon the disposal to be made of the material.

If garbage is to be fed to hogs, or is to be rendered, all rubbish, tin cans and other non-edible matters must be kept out of it.

If it is to be burned, combustible rubbish is an advantage; but if the haul is long to the incinerator it may be cheaper to

dispose of the rubbish nearer at hand and purchase coal to burn the garbage.

As a general average it may be said that rubbish is worth about one-fifth as much as coal for fuel for this purpose; therefore if it costs 50 cents a ton to haul rubbish to the incinerator and coal can be had for $2.00, the latter is the cheaper. Ordinarily additional haul of rubbish will cost about 20 to 30 cents per ton per mile, and the rubbish would be the cheaper fuel if the incinerator was only a mile further than the rubbish dump, and coal cost more than $1.50 a ton. But there may be no method for disposing of the rubbish so satisfactory as burning, and in some cases it may be mixed with the garbage for this reason.

If the garbage is to be dumped, the mixing of ashes and fine dry rubbish with it is an advantage, as it delays putrefaction and lessens the nuisance from flies and odors and the mixture is handled with less general nuisance than is garbage alone. Also the moisture of the garbage reduces the dust from the ashes. Mixing by the householder is therefore desirable if both garbage and ashes are to be dumped at the same place. But sometimes the ashes can be dumped with a much shorter haul than the garbage, and to mix them and haul the ashes the additional distance will add considerably to the cost.

If the garbage is to be buried as a fertilizer, tin cans are perhaps permissible, as they will quickly rust away; but bottles and all other rubbish should be excluded. Street sweepings can be mixed with garbage for burial.

If the rubbish is to be sorted out and sold, no other class of refuse should be mixed with it.

The number of separate collections of refuse, and of receptacles furnished and divisions made by the householder, will therefore depend upon the disposal to be made of the several classes. There is, however, another reason for classifying, in that some cities do not collect rubbish at all; others collect ashes but not garbage; still others, garbage but not ashes; while several collect ashes, and the garbage is collected by private parties. Of 189 cities, in 1915, 172 collected garbage,

either separate or mixed with refuse, 124 collected ashes, 109 collected rubbish, 59 collected refuse from stores, factories, etc., and 100 collected dead animals. In 77 cities, garbage, ashes and refuse were collected combined; in 73 the garbage must be kept separate from all other refuse.

Receptacles. *Garbage* should be kept in water-tight receptacles so that the foul water will not pollute the soil or floor under them; they should be non-absorbent so that they will not become saturated with such water; should be kept tightly covered to prevent the dissemination of odors and the scattering of the garbage by dogs, cats, rats or other animals, and should be of such size that one man can easily carry one and dump it into the wagon, but not so small that more than one is needed by the average family (to keep the work of collecting at a minimum). Probably the majority of cities specify a capacity of 9 to 12 gallons, and that the pails be of galvanized iron. A few cities call for iron in summer but wood in winter, with the idea that garbage is less likely to freeze in the wood, but this is questionable.

Quite a number of cities direct that the garbage is to be drained before placing in the pail, and this is desirable whatever disposal is to be made of it. In 15 or 20 cities where the garbage is burned, it must also be wrapped in paper (newspaper or a paper bag) after draining and before placing in the pail. (Trenton, N. J., more than doubled the capacity of its incinerator by requiring draining and wrapping.) This prevents to a large extent the soiling of the pail. It is not to be practiced when the garbage is fed to hogs.

Ashes should be placed in a receptacle which is tight; is of non-combustible material (as hot coals may be placed in it; this is not always required); is convenient to handle, and does not weigh more than 150 or at most 200 lbs. when full. Covers are desirable, but are seldom required. Galvanized iron stiffened by wood or iron strips and an iron band at top and bottom are probably the best; although stout wooden barrels are acceptable but not durable. The capacity should be about $2\frac{1}{2}$ to

$3\frac{1}{2}$ cu. ft. The usual size is 15 to 18 in. diameter and 24 to 26 in. high.

Rubbish is generally collected in almost any form so that it can be conveniently handled. Papers should be tied into bundles; carpets, clothing, etc., rolled up and tied; small matters placed in barrels or boxes; all matters which are to be collected at one time being made into as few units as possible.

There are several special cans on the market but not in very general use. In one kind the can is set into an outer iron receptacle which is buried in the ground and is provided with a lid. In another, the can is adapted for use with a special cart, to be described later. In the case of some large buildings burning a great deal of coal, the ashes are raised from a sidewalk vault, through an opening in the sidewalk near the curb, by a bucket elevator which discharges them directly into the ash cart; but most have a small freight elevator which raises them in barrels to the sidewalk level.

A few cities require a certain style of receptacle to be used, and furnish them to householders at cost; while two or more cities furnish the receptacles free.

Location of Receptacles. The refuse receptacles are taken by the collector from the back door of the house in some cities, from just inside the fence or property line in others, and from the curb in still others. Where there are alleys, the receptacles are generally collected from the alley. Of 154 cities, in 1915, 41 required the receptacles placed on the sidewalks; 9 at the lot line; 38 in alleys; 48 at the rear of the house; and 18 where they will be "convenient for the collector."

Art. 36. Collection of Refuse

The collection of refuse is, in the majority of cases, more costly than any kind of disposal. It is also performed in a less satisfactory way and causes more nuisance than reasonably perfect disposal. Great improvements are possible, but the expense has caused the rejection of most of those proposed.

Frequency of collection of *garbage* is more important in warm weather and southern climates than in cold weather, as the garbage becomes putrid and odorous more quickly in warm weather. On the other hand, the more frequent the collection the greater the cost, as it takes as long for the collector to empty a partly filled pail as a full one. If the garbage is to be fed to hogs, it should be collected daily in warm weather, and at least three times a week in cold weather. If mixed with ashes, less frequent collection is satisfactory so far as nuisance is concerned. The most common practice is three to six times a week in warm weather (we believe no cities collect on Sunday), and two or three times in cold weather.

Ashes can be collected at intervals dictated solely by convenience and cost to householder and city. A furnace in a house of average size will fill an ash barrel in two or three days in winter, and if the collections are made less frequently than this, the householder is required to keep two or more ash barrels in service. There is a little saving in time in collecting two ash barrels (both filled) at one time than at two separate times, but not much. In late fall and early spring one barrel will last the average house for a full week's ashes. Perhaps once in two weeks in summer (for kitchen ashes), once a week in fall and spring, and twice a week in winter gives the most satisfactory service.

During 1914, of 156 cities, 61 collected garbage twice in summer, 43 collected it three times, 25 collected it six times, 23 once, and 2 four times. Winter collections of garbage were made once a week in 50 cities, twice in 50, six times in 19, and three times in 18. Summer collections of ashes were made once a week in 35 cities, twice a week in 23, three times in 14 and six times in 9. Winter collections of ashes were made once a week in 37 cities, twice in 29, three times in 13, six times in 9, and four times in 1. Some cities collect garbage oftener than once a day from hotels, restaurants, etc. Several collect ashes less frequently than once a week in summer.

Rubbish is collected with ashes in many cities. When collected separately, some collect once a week, some once in two

weeks, a few once a year, some on notice by telephone or otherwise. Collections should be frequent enough to prevent an unsanitary collection of rubbish in cellar or yard.

Method of Collection. More than five, but probably less than ten, cities in the United States which collect refuse by city employees charged the householders directly for the service; but most pay for the service out of the general budget. About half the cities of the country collect part or all of the refuse directly by their own employees. About a third of the cities arrange with private parties for collection, three-fourths or more of these paying the contractor from the city budget, the others fixing the rates by contract, which rates the contractor collects from the householders. A common charge is 50 cents per month per family, the range being between 35 cents and $1.00 for all but a few exceptional cases. About one-sixth of the cities make no arrangements for collection, leaving the matter entirely to the householders.

There can be little question that municipal collection is the most satisfactory way. In large cities it is also the cheapest. In small cities and villages it may be cheaper to let the work by contract or permit farmers to collect garbage by private arrangement, and each householder to dispose of his own ashes and rubbish (the latter is generally burned out doors); but collections and disposal should be under strict supervision of the authorities as to carts used, place of dumping or burning, etc.

Garbage is generally collected by the collector emptying the pail into a wagon and returning it. In some cities where the garbage is taken from the back door, the collector carries a large pail with him and empties the private pail into this, thus saving him a second trip to return the private pail. In a few cities there are two collectors besides the driver, one going ahead and setting the pail on the curb, the driver emptying it into the wagon, and the third man returning it to the yard. Where the properties are large and more than half the time of the driver is spent in moving from one house to the next, it is generally cheaper to do without an assistant, the driver getting

and returning the pail. Where the pail is placed at the curb by the householder, the driver only is necessary.

A few cities, probably not more than ten, remove the pail without emptying it, leaving an empty and clean pail in its place. The filled pails are taken to the point of disposal, emptied, cleaned by hot water or steam, and returned by the collecting wagon. It is impracticable to return each pail to the house it was collected from; hence all pails should be alike, which is best secured by having the city furnish them, although a standard may be fixed, to be sold by local merchants. In Sewickley, Pa., this method is employed, the cans being furnished free. About one can is in service for each $3\frac{1}{2}$ persons. The cans are $12\frac{3}{4}$ in. diameter, $19\frac{1}{2}$ in. high, of 22-gauge galvanized iron, with heavy wrought iron hoops at top and bottom. The price averages about $1.20. They last three and one-half to four years. One team collects 285 cans a day in four trips, the amount of garbage and combustible rubbish averaging 4 tons. This method is the most sanitary and inoffensive in use, since no garbage is exposed to the air during collection. The difficulty of compelling the use of or payment for standard cans, or preventing abuse or theft of publicly-owned cans in large cities, is probably one reason why few if any such have considered it.

The Sewickley wagon consists of a bed 7 ft. wide by 14 ft. long, surrounded by uprights and a chain, on which 72 cans are placed. In a few Ohio cities where the cans are removed, the wagons have two floors, one above the other, each carrying 30 10-gallon cans, or a total capacity of 600 gallons.

Collection Wagons. There are several types of garbage wagons. Probably the most common is a cart with a steel body, with the rear end sloping so as to require no tail board and to empty easily by dumping. Others have steel boxes, or wood lined with zinc, from which the garbage must be shoveled. A few are used having one or more metal tanks carried on a wagon body, which tanks can be removed at a disposal plant or transferred to a truck or a steam or street railway car.

Farmers and collectors in a small way sometimes use hogs-

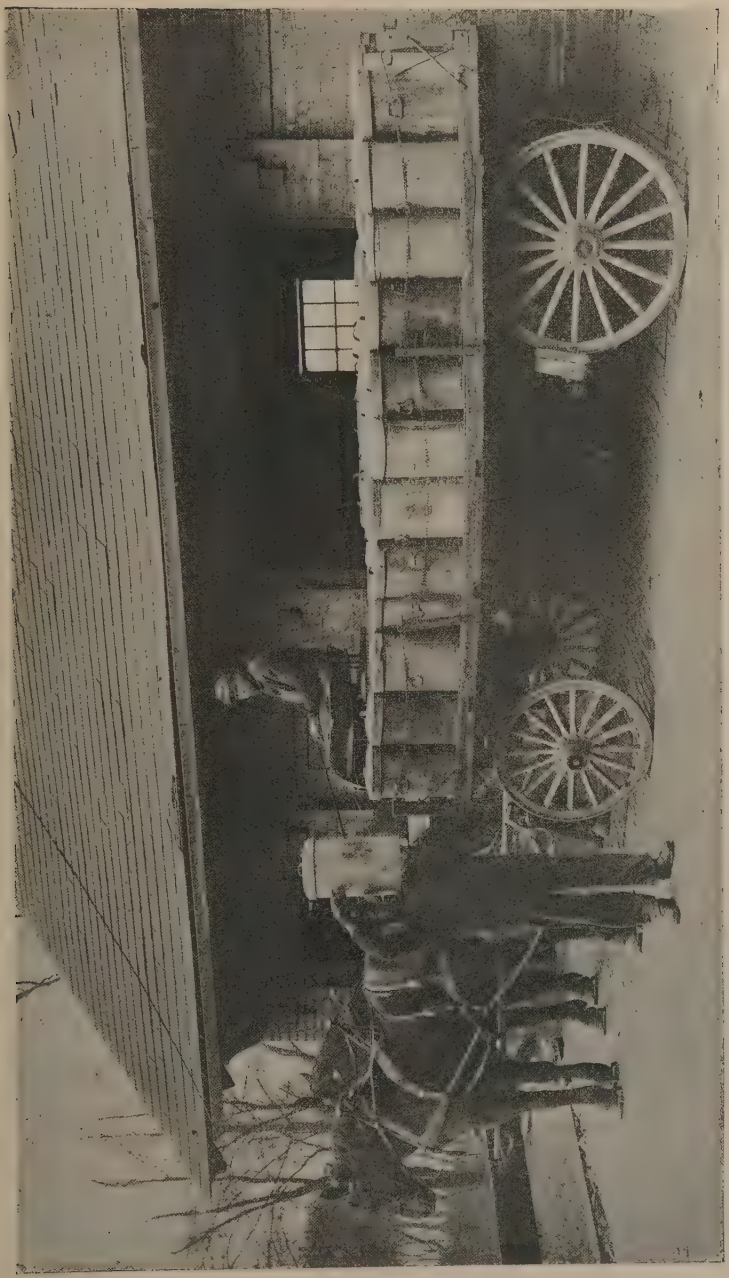


FIG. 101.—Wagon Collecting Garbage in Service Cans, Sewickley, Pa.

heads or tight barrels carried in an ordinary wooden box wagon. These are apt to slop over when full and garbage is spilled into

FIG. 102.—Collecting Garbage in Service Cans by a 3-Ton Truck, Syracuse, N. Y.

FIG. 103.—Cart for Garbage and Ashes, New York.

the wagon when emptying the pails, and the wagon box and outside of the barrels are generally foul and objectionable to smell

and sight. This method of collecting is forbidden in most well regulated towns.

Whatever the kind of wagon or tank, it should be kept covered except at the instant the garbage is being emptied into it. Covers of canvas, hinged wooden lids, or hinged or sliding sheet iron covers are in use. The iron covers on iron tanks generally rattle and are most objectionably noisy. Canvas is the ligthest and easiest to handle, but becomes filthy unless frequently washed, and frays and rots, in spite of which it is probably the best cover so far tried. The chief difficulty with all kinds is in compelling the drivers to keep the garbage covered with them. Constant inspection and fines should remedy this.

The requirements for a satisfactory garbage wagon are that it shall be water-tight; shall be easily cleaned, containing no cracks, sharp angles, offsets or other depressions or projections not easily flushed out by a stream of water or reached by a broom; can be so dumped as to discharge all its contents; is hung low so that the pail need not be lifted more than 4 ft. 6 in., or 5 ft., as a maximum, above the street to empty it; is provided with some method of covering so that all the garbage is kept from air and sight except while a pail is being emptied, and then only a small part is uncovered; is not noisy; is of the size adapted to the particular service; is of material which is non-absorbent and durable; is generally stout in construction; and with a method of locomotion adapted to frequent starting and stopping. The size and method of locomotion will be considered further on; the reasons for the other requirements are self-evident.

Ash wagons need not be water-tight, but should be dust-tight. Tail-board dump-carts, bottom dump wagons, dump-pole wagons, and ordinary box wagons are sometimes used, but none are as tight as an ash wagon should be. The same type of steel body used for garbage is good for ashes also; or a tight wooden box with high sides may be used. A cover is even more desirable than for garbage, to prevent the ashes being blown about. The requirements are, that the wagon be dust-tight; easily dumped; hung low, the top not more than 4 ft. or

FIG. 104.—Special Form of Garbage Can and Collecting Wagon—Ochsner System.

The wagon is divided into compartments, each covered by a separate sliding lid. The can also is covered by a sliding lid. When the can has been placed inverted on the wagon top, both lids are drawn out and the garbage falls into the wagon without being exposed to the air. The lids are closed again before the can is removed. An American design (not yet used in regular service by any city) embodies the same principle.

4 ft. 6 in. above the ground; provided with a cover; not noisy; of the most economical size; of durable material and stout construction, and with a method of locomotion adapted to frequent stopping and starting. The height is especially important because of the weight of many ash barrels, especially after a rain.

Ashes and garbage collected together require about the same kind of a wagon as ashes alone.

Rubbish is much lighter than ashes, and requires a larger wagon to secure an economical load. Much of it consists of large pieces of wood or other light material, mattresses and the like, but some is frequently fine,

like dust, sawdust, etc., which will sift to the bottom of the load. The bottom of the wagon should therefore be tight, but the top may be open like a rack. As most of the material is light, the sides of the wagon can be quite high. A cart or wagon with a fairly tight wooden box body carrying an extension of slats or racks on top is generally found satisfactory. New York uses a cart with a drop axle so that it hangs within a foot of the ground; the wood sides are about 4 ft. high, the rear end being hinged to open like a door; and

FIG. 105.—New York Rubbish Cart.

a rack 4 or 5 ft. high is fastened on top of the body. Capacities of 6 to 15 cu. yds. are in general use.

The *size of cart* or wagon is a matter requiring careful consideration, which should include a study of the local conditions as to grades, kinds of pavements, distance refuse is to be hauled, strength and endurance of native draught animals, weight per cubic yard of material collected, frequency of collection, where refuse receptacle is taken from, and other factors. Where a given class of refuse is to be hauled several miles from any section of the city, it may be economical to transfer the refuse

from a small horse-drawn wagon to a motor truck or a railway car at a loading station; or to draw the wagon as a trailer behind a motor wagon.

One horse can draw about two tons on a good road on a level, or about one ton on a 4 per cent grade; but on an unpaved alley the limit may be half this. It is frequently possible, however, to so arrange the routes (providing the disposal plant or grounds are lower than the greater part of the town, as they should be) that the hauling up hill will always be with empty wagons and down hill while loading or when loaded, in which cases greater loads can be drawn than on a level.

Time Study. The relative times occupied in hauling the empty cart, in collecting and in hauling the filled cart to the disposal point are of great importance. A careful study of this in Milwaukee showed that it required about three and one-quarter minutes per building to remove garbage pails from the rear of the house and go to the next house, five to eight minutes being required in some districts. If the pail is set at the curb by the householder, about half a minute to a minute is sufficient. Here the teams traveled about 5 miles in each trip while not collecting, and collected along a distance of 500 to 2000 ft. A draught horse will average about $2\frac{1}{2}$ miles per hour, or 3 miles on short runs. A motor truck will carry 5 to 10 tons, or even 20 tons when loaded on trailers, at 8 to 10 miles per hour. Using the local wages of collectors and truck chauffeurs, and the cost per day of horses and carts (either cost to hire, or cost to feed and maintain, with interest and depreciation), and comparison can be made of different sizes of wagons, routes, location of transfer and loading stations, etc., which will give the maximum economy.

A one-horse cart is cheaper than a two-horse wagon for *collecting*, but not for hauling, for when a two-horse team is used the load during half the time of collecting could be drawn by one horse and the time of the other horse is being wasted. Motor trucks are not economical for collecting for the same reason and because of time lost in stopping and starting and energy wasted while standing and moving slowly. Probably the method which

is theoretically most economical in many cases would be to arrange collection districts so that each cart could reach a transfer point just as it completed its load, the horse being there harnessed to a waiting empty cart; the full carts being taken as trailers (or their bodies transferred to a truck) by a motor truck to the disposal point. The horse would proceed at once to collect another cart-load, and the process be repeated. This would require careful routing of teams and would probably be impossible of perfect accomplishment; it also presupposes that there would be enough cart-loads to keep the truck constantly busy.

In several cities the cart-loads are brought to one or more loading stations at convenient points, where large trucks, or cars run on steam or street railways, are filled by dumping the carts from an elevated road or ramp. This transfer of loads adds to the expense, and is economical only when the haul is long and the quantities large.

For average streets, the loads (net) carried in one-horse garbage carts in most cities vary from 1300 to 2000 lbs., and for a two-horse wagon from 3600 to 4400 lbs., averaging 1600 and 4000 lbs. respectively.

The number of carts required and the routing of these so as to secure maximum efficiency require careful study of the city and calculation based upon units determined as accurately as possible. Such a calculation may be made as follows:

Assume that investigation has determined that the average garbage production is 4 lbs. per capita per week and 25 lbs. per family or other collection unit. (This will vary with the various districts of a city. A poor district might average half this; while one hotel might fill a cart.) That the horses used on the pavements prevailing travel 200 ft. per minute while in motion during collection, and average 3 miles per hour while hauling a load to the disposal point and returning empty. That the pails are set out on the curb by the householders or assistants to the driver, and that one-quarter minute is required to empty the pail, including stopping and starting the cart. That the

average net load for one horse is 1600 lbs. and for two horses 4000 lbs. That the wages of the driver (who walks along the curb and empties the pail) is $2, and the hire of one horse and cart is $1.50 and of two horses and wagon is $3.00; each for an eight-hour day. That it requires ten minutes to dump. And that all the time is used. The cost of one-horse cart and man is then 0.73 cent per minute; that of two horses and one man is 1.04 cents per minute.

If garbage is collected from each house once a week, the one-horse cart can collect from 64 families per load; the two-horse wagon from 160 families. If there are two collections a week, the loads will comprise garbage from 128 and 320 families respectively; if three collections, 192 and 480 families respectively.

Assume the length of street divided by the number of houses on one side equals 60 ft. Then the time of one filling is $(\frac{60}{2\,0\,0}+\frac{1}{4})$ minutes $=\frac{1}{2\,0}$ minute.

To collect from 64 houses requires $64\times\frac{1}{2\,0}=35.2$ minutes, costing 25.7 cents for a one-horse cart; which equals 32.1 cents per ton.

Similarly the cost of filling either cart or wagon, on a once, twice or three times a week schedule can be calculated.

Hauling to the dump and return requires 20 minutes to a mile, costing 14.6 cents for the cart and 20.8 cents for the wagon, which is equivalent to $18\frac{1}{4}$ cents per ton and 10.4 cents per ton respectively. Dumping, at ten minutes, costs half of these sums, or $9\frac{1}{8}$ and 5.2 cents respectively. A table can then be made up similar to that on page 361.

In any given city there will be collection districts at various distances from the disposal point. If this point is in the city, these distances will vary from nothing to that of the section farthest from that point. If the average haul for the nearest district assigned to one cart is $\frac{1}{2}$ mile (1 mile both ways), and there are two collections a week, that cart could collect four loads in one day and have one hour and sixteen minutes left. But it would require one hour and forty-one minutes to collect a regular load, twenty minutes of which is used in going and

TABLE XXX.—TIME REQUIRED FOR COLLECTING GARBAGE AND HAULING SAME. PER LOAD

Number of Collections	Distance Cart Is Hauled While both Full and Empty					
	1 Mile	2 Miles	3 Miles	4 Miles	6 Miles	8 Miles
One-horse Carts, Load 1600 Pounds. Pails Collected at Curb						
One collection per week	1 hr. 5 min.	1 hr. 25 min.	1 hr. 45 min.	2 hr. 5 min.	2 hr. 45 min.	3 hr. 25 min.
Two collections per week	1 hr. 41 min.	2 hr. 1 min.	2 hr. 21 min.	2 hr. 41 min.	3 hr. 21 min.	4 hr. 1 min.
Three collections per week	2 hr. 16 min.	2 hr. 36 min.	2 hr. 56 min.	3 hr. 16 min.	3 hr. 56 min.	4 hr. 36 min.
Six collections per week	4 hr. 1 min.	4 hr. 21 min.	4 hr. 41 min.	5 hr. 1 min.	5 hr. 41 min.	6 hr. 21 min.
One-horse Cart, Load 1600 Pounds. Pails Collected from Rear of House						
One collection per week	1 hr. 53 min.	2 hr. 13 min.	2 hr. 33 min.	2 hr. 53 min.	3 hr. 33 min.	4 hr. 13 min.
Two collections per week	3 hr. 16 min.	3 hr. 36 min.	3 hr. 56 min.	4 hr. 16 min.	4 hr. 56 min.	5 hr. 36 min.
Three collections per week	4 hr. 40 min.	5 hr. — min.	5 hr. 20 min.	5 hr. 40 min.	6 hr. 20 min.	7 hr. — min.
Six collections per week	8 hr. 49 min.	9 hr. 9 min.	9 hr. 29 min.	9 hr. 49 min.	10 hr. 29 min.	11 hr. 9 min.
Two-horse Wagon, Load 4000 Pounds. Pails Collected at Curb						
One collection per week	1 hr. 58 min.	2 hr. 18 min.	2 hr. 38 min.	2 hr. 58 min.	3 hr. 38 min.	4 hr. 18 min.
Two collections per week	3 hr. 26 min.	3 hr. 46 min.	4 hr. 6 min.	4 hr. 26 min.	5 hr. 6 min.	5 hr. 46 min.
Three collections per week	4 hr. 54 min.	5 hr. 14 min.	5 hr. 34 min.	5 hr. 54 min.	6 hr. 34 min.	7 hr. 14 min.
Six collections per week	9 hr. 18 min.	9 hr. 58 min.	9 hr. 58 min.	10 hr. 18 min.	10 hr. 58 min.	11 hr. 38 min.
Two-horse Wagon, Load 4000 Pounds. Pails Collected from Rear of House						
One collection per week	3 hr. 58 min.	4 hr. 18 min.	4 hr. 38 min.	4 hr. 58 min.	5 hr. 38 min.	6 hr. 18 min.
Two collections per week	7 hr. 26 min.	7 hr. 46 min.	8 hr. 6 min.	8 hr. 26 min.	9 hr. 6 min.	9 hr. 46 min.
Three collections per week	10 hr. 54 min.	11 hr. 14 min.	11 hr. 34 min.	11 hr. 54 min.	12 hr. 34 min.	13 hr. 14 min.
Six collections per week	21 hr. 18 min.	21 hr. 38 min.	21 hr. 58 min.	22 hr. 18 min.	22 hr. 58 min.	23 hr. 38 min.

COST PER TON OF COLLECTING GARBAGE AND HAULING SAME

Wages, $2 for 8 hours. Horse and cart, $1.50, two horses and wagon, $3.00

One-horse Cart, Load 1600 Pounds. Pails Collected at Curb						
One collection per week	$0.595	$0.777	$0.96	$1.14	$1.51	$1.87
Two collections per week	.916	1.10	1.28	1.45	1.82	2.18
Three collections per week	1.24	1.42	1.61	1.78	2.15	2.51
Six collections per week	2.20	2.38	2.57	2.75	3.12	3.48
Two-Horse Wagon, Load 4000 Pounds. Pails Collected at Curb						
One collection per week	$0.614	$0.718	$0.822	$0.926	$1.13	$1.34
Two collections per week	1.07	1.17	1.28	1.38	1.59	1.80
Three collections per week	1.53	1.63	1.74	1.84	2.05	2.26
Six collections per week	2.91	3.01	3.12	3.22	3.43	3.64

coming; leaving time to collect only two-thirds of a load on the fifth trip.

Taking a district 3 miles from the disposal point (6 miles both ways), a cart could make two collections in a day and one hour and eighteen minutes over. But as it would take it two hours to go to its district and return, this time must be wasted. If, however, this cart could be given another district with a $1\frac{1}{2}$-mile haul to work in conjunction with this, two loads from the nearer district and one from the farther would require just eight hours.

It is seen from the table that, under the conditions assumed and with two collections a week, a two-horse wagon is cheaper than a one-horse cart when the haul both ways exceeds 3 miles. If a wagon be assigned to the 8-mile haul it would collect but one load in five hours and forty-six minutes, leaving it two hours and fourteen minutes. The most economical use to make of this time would be to harness the horses separately to two carts and have them collect somewhere within one mile of the disposal point; for it requires three hours to fill a wagon, aside from the haul, and in the hour and a half left for actual collecting, only half a wagon load, or one ton, could be collected, while a cart could be filled in this time and the two carts would collect 3200 lbs., or 60 per cent more.

The only practicable method yet worked out to meet such difficulties is to assign to each cart a short haul and a long one, so selected that one load from each, or one from one and two from the other, will use up the eight-hour day.

Economy requires (1) that each horse secure in each load the maximum amount which he can haul without overworking, before delivering it; (2) that one horse only be employed to a collecting unit (for with a team, the second horse is of no use until after half the load has been collected); (3) that two or more horses (or other equivalent motive power) be used for a hauling unit, thus saving in wages of driver and in weight of wagon relative to load; and (4) that all the working hours be used. The second and third cannot both be secured except by the use of

loading stations, tractor and trailers, or other method the expense of which would probably make it prohibitive for any but large cities; and the selection of either one-horse or two-horse vehicle for both collecting and hauling should be made as indicated by such calculation and table as the above.

The same general method may be applied to calculating with reference to ash removal, rubbish removal, or mixed garbage and ashes; except that the unit per house will be different and the time required to empty each barrel is greater.

Art. 37. Removal of Night Soil

Night soil is the name usually given to the contents of cesspools and privy vaults—human excrement with or without dirty water from sinks and other parts of the house. Owing to the flushing-water from the bath-room as well as the other dirty water, these contents are generally more or less fluid, and can frequently be pumped. They are removed in tight barrels or a tight wagon—commonly the former when shoveled or bailed out, the latter when pumped. The barrels or tubs (called "pitting barrels") are of 20 to 30 gallons capacity, of wood, well hooped and provided with an iron cover which can be made tight by a simple fastening, and with handles for carrying. The Providence tub, holding 25 gallons, costs about $3.50 each. The 20-gallon barrel of the Odorless Excavating Co. of Boston costs about $4.50 to $5.00. It is generally provided by city ordinance—but not so generally enforced—that when filling these, the vault or cesspool shall be covered with a tent "made of canvas, and so constructed as to give space for one or more barrels, and so erected as to form a close joint with the walls of the privy building and the pavement or ground, completely enclosing the door, and so secured that no odor can escape except through the air-hose. The air-hose shall be made of some air-tight material, expanded by a spiral wire or other suitable device, and shall have an inside diameter of not less than 5 in., and shall be at least 10 ft. in length. When in service, the air

hose shall be attached with a tight joint to the tent, at a point not less than 4 ft. from the ground, by one end, and the other connected by a practical air-tight joint with the deodorizing apparatus, or furnace when used, so that no air can enter below the grate of the latter except through the air-hose from inside of the tent." (Philadelphia ordinance.)

Preferable to this, however, is the pumping of the contents (made more liquid, if necessary, by the addition of water) directly into a tank wagon, there being no contact with the air or opportunity for the escape of odors at any part of the operation. The hose through which the contents is pumped is generally 4 in. in diameter. A special "odorless excavating" pump is used, the ordinary capacity of which is about 6000 gallons an hour, operated by two men. The usual wagon is of wood staves or steel plates, holding 250 to 450 gallons. As this method of emptying a vault is inoffensive it can be performed at any time.

The charges fixed by several cities for removing night soil range from $1.35 to $5.40 per cu. yd., with a minimum charge in several cities of $2.00 to $3.00. Florence, N. C., charged 15 cents per month for each privy, doing the work itself. Frequency of cleaning is regulated by ordinance in several cities, being required at intervals limited to minimum periods varying from a week to a year.

CHAPTER IX

MARKETS, COMFORT STATIONS AND BATHS

Art. 38. Municipal Markets

Public markets are owned and operated by a great many cities as municipal enterprises, and in many other cases by private individuals. Structurally there need be little difference between public and private markets if they are enclosed in buildings. Some cities, however, simply designate certain streets or other public areas in which farmers can station their teams and sell directly from the wagon. As general street traffic is increasing, however, this practice is being discontinued, for it practically withdraws these streets from use as highways during market days; and a number of cities have built, to replace these street stands, market houses, or wagon stands on land not part of any street. Where wagons back up to a curb side by side, it is customary to assign a certain length of curb to each. Seven feet is perhaps most common, but 8 ft. is assigned by some cities.

Structures. There are several varieties of structures used for public markets. The simplest is a paved walk or series of parallel walks, against both sides of each of which the teams back, the walk serving both to afford a dry, clean passageway for purchasers and to fix the positions of the wagons. The next step is to build roofs over the walks, preferably projecting about 5 ft. beyond each curb so as to protect the seller and his goods from rain and sun. In some cases the walk is made sufficiently wide to permit of stalls or tables, one in front of each wagon, on which the produce may be displayed. For the benefit of the horses, a hitching shed may be provided where these, removed from the wagons, may rest and eat under shelter; it also prevents the littering of the driveway, and the destruction of the pavement by the pawing of horses standing harnessed to the wagons.

FIG. 106.—Farmers' Open-air Produce Market, Washington, D. C.

FIG. 107.—Hitching Shed at Public Market, Madison, Wis.

Other markets are so located that produce may be brought in by rail, sidings from the railroad being run into or alongside of unloading platforms, which are roofed over. These would generally be for wholesale rather than retail trade, although where market gardens are 10 miles or more away, farmers may use the railroad rather than teams for bringing produce for retailing.

Probably the most common kind of public markets established in recent years, however, especially in large cities, consist of enclosed buildings, in which are stalls which retailers rent from the city or private owner. One stall may be used by a number of farmers, each having a certain day of the week, or by one who has an attendant there two or perhaps six days of the week; or by regular dealers, who find here lower rents and more purchasers than in a separate store. Such a building may contain from a dozen to a hundred or more stalls.

Sanitation. In any of these markets sanitary conditions should be the first consideration. For this reason it is desirable to remove the horses from wagons lined along the walks, because of their droppings and urine. All vegetable matter, scraps of meat and fish and other refuse matter should be cleaned up and the walk and street washed clean at the end of every day. All stationary stands should be so constructed that no such matters can lodge in cracks or corners or fail to be removed by the daily flushing; nor should any material be used which will absorb water or other fluids. In the case of a building, all of the floors, walls, stands and other fixtures must be so designed that every part can be flushed out or scrubbed off. Ventilation should be provided for, and a certain amount of heating in winter. If goods are to be stored more than one day, refrigerating appliances are necessary, and in the most modern markets refrigerating pipes or ice are introduced into the cases where meat or fish are displayed for sale.

Structural Details. In Rochester, N. Y., steel sheds about 50 ft. wide cover a walk 18 ft. wide and extend beyond to protect a wagon and horse on each side. Three feet from the curb is a summit to hold the wagon in place when backed against the curb,

FIG. 108.—Public Market, St. Paul, Covered Platforms Elevated above Driveways.

from which summit the surface slopes down to a gutter 11 ft. from the curb. Separating this gutter from another (beyond which is another walk and shed) is a roadway proper of 42 ft. Here also are railroad sidings and unloading platforms and sheds.

St. Paul has a similar market, in which the walks are 18 ft. wide and the sheds 45 ft., with 54 ft. driveways between. Minneapolis has a market with 12 ft. walks or platforms, with 44 ft. between them; 6 ft. is allowed for each wagon. Detroit has a market with platforms 25 ft. wide and sheds over them 75 ft. wide.

The walks in such markets should slope toward one or both edges and be paved with concrete or other durable, smooth pavement. The roadway, and especially the part where the horses stand, should also be paved with a smooth and durable pavement which can both be cleaned easily and withstand the pawing of the horses' hoofs. The smoothest of granite block or hard brick is perhaps the best. As there will be large quantities of vegetable and animal scraps scattered on the street, ordinary open sewer inlets should not be used, but a surface inlet covered with a strainer is most desirable, and these should be placed at frequent intervals in the gutter. In spite of these, some small putrescible matters will reach the drain, and it is well to discharge this into a catchbasin which has a scum board or trap to hold back floating matters, which catchbasin should be cleaned at the end of every market day, after the cleaning up of walks and roadways.

Buildings which are used for markets are generally one story high; or at least it is found that only the ground floor is desirable for market purposes. Owing to the large numbers of people which may crowd the market and the odors of meats, fish and vegetables, the market room should be quite high-ceilinged and the windows or other means of ventilation should be ample. For light, windows extending well up to the ceiling or roof, and skylights are desirable (in Southern cities these are often painted or curtained to keep the direct sunlight from heating the building and especially the meat and fish), and electric lights for early morning, evenings and dark days.

The *floors* should be durable, non-absorbent, without joints, cracks or breaks into which liquid or fine organic matters can enter. Concrete, terrazzo, asphalt, and vitrified bricks or tiles with cement joints are among the floors used. Asphalt is sometimes used within the stalls, even when other harder paving material is used in the aisles, because it is drier, less cold and easier for the feet of the salesmen. In other markets wooden gratings or mats are placed in the stalls for this purpose, but these it is impossible to keep clean and dry. The floor should be carefully graded so that numerous drains will receive the flushing water from every part of it. In some markets the walks are crowned, with a gutter on each side; in others the walk is slightly dished and the drains placed in the center. The center drains are inconvenient to customers, and the former plan is preferable.

All *stands*, counters, etc., should be so built that nothing but the legs shall come within a minimum distance (usually set at between 6 and 12 in.) of the floor, so that mops or brushes can easily reach every part and the whole floor of the building be flushed out. If partitions are used, they should be of concrete, tile or other non-absorptive material and the angle with the floor be preferably coved or rounded, and a drain opening be placed inside of each enclosure.

The *drain* inlets should preferably be of a kind which can be covered with a solid plate at all times except when the floor is being washed, to prevent organic matters getting into them, these plates being flush with the floor and fastened in place. Under the plate should be a strainer. In cleaning, the floor would be swept up and all matters removed which can be by broom, after which the plates are removed and the floor flushed.

The *aisles* or passages between stalls are seldom less than 7 ft. wide, and $8\frac{1}{2}$ to 12 ft. is common. Baltimore has a 30-ft. central aisle, but this seems unnecessary. The most common arrangement is to have stalls along the sides of the market and either one aisle between them, or a central row of stalls with two aisles. Cross aisles are common at intervals of 20 to 40 ft.

The size of *stalls* varies, but is generally 7 to 12 ft. width and 8 to 20 ft. depth. In one of the most complete, the 23rd St. market, in New York, the stalls average about 12×17 ft.; in another market built in 1915 in the same city they are 8×10 ft. In Raleigh, N. C., the meat stalls are 12×16 ft., which size is also used in Chattanooga. In Boston's Quincy market the stalls are $7\frac{1}{2}\times16$; in Cleveland, O., 7×7 ft.; in Montreal, Quebec, 9 ft. wide by 15 to 20 ft. deep; in Toledo, 8×14; Newark, N. J., 8 ft. square (but most dealers occupy two or more stalls); Knoxville, 14×14.

The *tables* or stands for fish, vegetables, etc., are generally 2 ft. 10 in. to 3 ft. high. Wood was formerly used, but in most recent markets cement, marble, glass, enameled iron or other non-absorptive and easily cleaned material is used. If of wood, the stands should be painted a light color, and kept painted. In Seattle, tables 3×5 ft. of pipe and galvanized iron are used. Fort Wayne constructed tables $5\times2\frac{1}{2}$ ft. of concrete throughout, the top a concrete slab $1\frac{3}{4}$ in. thick reinforced with woven wire, the mixture 1 to 2.

A wooden meat table or block is generally used. Those in Washington, D. C., consist of legs turned out of 4×4 Georgia pine, connected with 2×3 oak braces at the bottom and by $1\frac{3}{4}\times5\frac{3}{4}$ oak apron pieces at the top. The top is made of white oak strips $2\frac{1}{2}$ in. thick and 6 in. wide, with V-shaped tongue and groove, the several pieces being tied together by $\frac{5}{8}$ in. rods set not more than 2 ft. apart and provided with nuts and washers, the heads countersunk. The corners are all rounded. In the same market, shelves for fish are of $1\frac{1}{2}$ in. boards, 1 ft. 4 in. wide, covered with 14 oz. zinc carried up over a beveled edging strip $\frac{1}{2}$ in. thick to hold the water, which is removed by a 1-in. lead pipe in the center.

General Appliances.—Most modern markets have refrigerators, with elevators (if they are in the basement or cellar) or overhead track for transporting meat from them to the stalls. In a New York market an ammonia machine lowers to 20° F. brine in a brine tank 24 ft. square by 5 ft. high, which is pumped

through a distribution system to each of 150 stalls through pipes from 6 in. to $1\frac{1}{4}$ in. diameter and is returned through other pipes of the same size.

There should be water connections (preferably both hot and cold) at every stall, and hose connections for flushing out the market. Provision should be made for disposing of meat, fish and vegetable refuse, either by removal by the city at least once a day or by destruction in an incinerator.

A few cities maintain municipal abattoirs. Grand Forks, N. D., has one in a building 30×50 ft., one story and basement, constructed throughout of brick and concrete, costing about $12,000. (For description, see *Municipal Journal*, Sept. 10, 1914.)

Art. 39. Public Comfort Stations

These should be placed where the public congregates in the largest numbers—in public squares, market places, parks, street railway intersections and congested districts; also in public buildings such as city halls and court houses, libraries, etc. They are especially necessary for those who are comparatively unacquainted with the neighborhood, and their location, as well as the entrance allotted to each of the sexes, should therefore be made prominent by signs. Either there should be a building for each sex or (what is more common and economical) a building with two entirely separate rooms, the entrances to them as widely separated as the plan and surroundings will permit. Several small stations scattered among the localities where they are needed are preferable to double the total capacity in one or two large stations. New York has two or three very large stations poorly located which are never more than 50 per cent in use.

Up to five years ago practically all such stations were placed under ground, but of those built recently probably three-fourths have been built above ground. In some cases they must be placed under sidewalks because there is no other public area

FIG. 109.—Above-ground Public Comfort Station, Cadwalader Park, Trenton, N. J.

FIG. 110.—Interior of Public Comfort Station, Showing Closets and Urinals Underground Construction.

available; but where a park or parked area can be used, they should, in the author's opinion, be always above ground. If any structures need ventilation for the frequent renewal of air, removal of odors and drying of damp surfaces, it is these. They also need abundant sunshine, because it is the best and cheapest germicide we have (there is little if any germicidal value in the odor destroyers used in such places) and to assist in drying the floors and walls after the frequent washings which they should receive. With all classes and conditions of the washed and unwashed using these rooms, no means of improving their sanitary condition should be neglected. The above-ground position also assists in giving them the publicity which is necessary for their maximum usefulness.

A committee of sanitarians, in reporting in 1914 on New York's comfort stations, recommended that the "comfort" should not be confined to toilet conveniences, but that public telephones, bootblack stands, news stands cigar stands and other small conveniences be located in such buildings, either tended by the attendants of the toilet rooms or granted as concessions. In either case, a considerable part of the cost of attendance might be met in this way. Pay toilet rooms also are recommended; Washington, Baltimore, Boston, Cincinnati, Springfield, Mass., and other cities find them appreciated and a source of income.

Construction. As to construction, the design should be simple, with as few interior corners as possible, and all parts within sight of a single attendant in each room, passageways straight and wide, and the whole easily ventilated and flushed out. There should be a heating plant, preferably in the basement; an adequate supply of hot and cold water for lavatories and for cleaning purposes. The plumbing should be most substantial in construction and simple in design; it should be impossible for visitors to detach any part of the fixtures, and it is desirable that most of the mechanism be hidden from the users but easily accessible to the attendant. Plain glass is undesirable in windows which come within $6\frac{1}{2}$ ft. of the ground or if there are other buildings near by; but there should be abundance

of translucent, non-transparent glass in windows or skylights under such conditions. Forced ventilation is desirable, although abundant window openings will suffice for small stations.

The floors should be of non-absorbent, waterproof material, like concrete, terrazzo, tile or asphalt. The walls also should be of similar materials or marble, slate or glass, for at least 6 ft. above the floor. Stall partitions should clear the floor by at least 8 or 9 in., and nothing should interfere with the flushing of the entire floor and its draining to one central outlet in the center of the room, toward which the entire floor should slope. It is desirable that all angles between floor and walls be rounded or "coved." The partitions between stalls should be of slate, marble, structural glass, enameled iron or other non-absorbent material easily cleaned, as should also the partitions and backs of urinal stalls. All walls and partitions are preferably white or light in color, both to ensure cleanness and to make the room light in all parts.

Some recommend no doors in the stalls; others, swinging doors without latches or locks; and still others, doors which latch on the inside. Personally the writer prefers a door held open by a spring hinge when not in use and provided with a drop-over latch. A simple floor-trough urinal without partitions is the easiest to keep clean, but partitions are commonly used in modern stations.

Most of the modern stations have a passage $2\frac{1}{2}$ to 4 ft. wide behind the toilets and urinals (which are placed in a row against a wall which separates the toilet room from this passage), in which are located the piping, both water and drainage, the flushing tanks, the ventilating ducts, etc., and which is accessible to the attendant only. It economizes if one passage and, to a certain extent, one set of pipes be made to serve both men's and women's toilet rooms, which may be effected by placing the toilets of the two rooms in two parallel lines with the passage and its two walls separating them.

Perhaps the simplest and most economical plan for a building is to make it in the form of approximately a square with a

passageway $2\frac{1}{2}$ ft. wide dividing it into two equal rectangles. The entrances to the two apartments would be at opposite ends, the urinals near the men's entrance and a retiring room occupying a corresponding position on the women's side. In each side, the toilets (and the urinals on the men's side) are ranged along the wall of the dividing passage. In the opposite wall are windows, and along this wall are washstands, drinking fountain, telephone booth, bootblack, cigar stand, etc. In a large station the last four should be in a waiting room or vestibule separated from the toilet room.

Details of Stations. Brief descriptions of some recent stations will give details of modern construction.

Cadwalader Park, Trenton, N. J. Above ground. Building 30×31 ft., brick and stucco on stone foundation. Floor, concrete covered with hexagonal tile, 6 ft. wainscot of green glazed tile; above this, sand-finished plaster. Men's room 9′ 5″×29′, 3 windows, swinging sash; 4 toilets, 6 urinals, 2 lavatories and sink, 2 ceiling lights. Women's room 10′ 5″×29′, 2 windows; 8 toilets, 2 lavatories, 1 sink. Toilets and urinals all along parallel walls with passage between. Building cost $3115; plumbing, $1370.

St. Louis. Underground. Pavement above; vault lights. Men's room, 13′ 8″×19′ 10″; floor, concrete. Urinal floor-trough, 14′ long, 1′ 9″ wide, marble slab. 6 toilets divided by marble slabs, each 3′×4′ 6″. Also 5 showers, open. Women's room, 12′×17′ 6″; 8 toilets and 5 showers. On each side, attendant's room, 13′ 8″×4′ 10″, maple floor. Between men's and women's sides, boiler room 9′ 4″×31′; back of this, ash room, 5′ 4″×16′ 6″ and fuel room, 8′×16′ 6″. Cost, $16,500.

New York, Grant's tomb. Partly above ground, shelter on roof. Men's room 16′×27′; 10 toilets and 6 urinals, 2 flush-tanks for latter. Women's room, 16′×15′; 10 toilets. Women's dressing room, 12′×25′, 2 washbasins. Women's attendant's room, 15′×15′; men's attendant's room, 7′×9′. Boiler room, 15′×17′; coal room, 15′×10′. Floors $2\frac{1}{2}$″ white vitreous hexagonal tile, sanitary cove along base of walls. Wainscot, 7 ft. high, polished white opaque glass; above this, plaster. Partitions between rooms, 4 in. porous terra cotta. Doors to stalls hung with two spring hinges, holding doors open when not in use. Fastened shut with extra heavy drop-over latches. Drain pipes, 4″ and 6″; numerous unions. Floor drain and slop sink branches, 3″ pipe; others 4″; vertical pipes, 2″. Water supply branches, $\frac{1}{2}$″ to basins and drinking fountains, $\frac{3}{4}$′ to other fixtures. Each group of fixtures has separate controlling valve with valve-

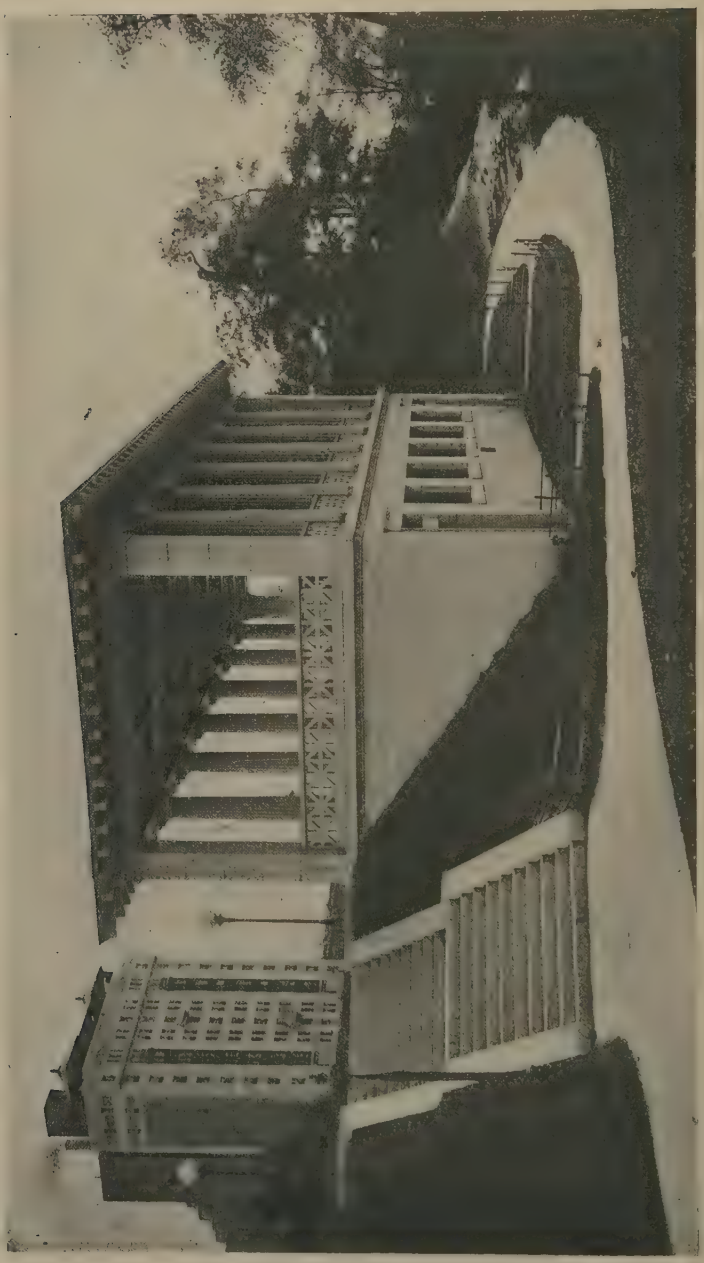


FIG. 111.—Public Comfort Station Below; Shelter Above. Near Grant's Tomb, New York.

emptying pipe. Each flush tank and fixture has separate controlling valve, all with detachable key handles. A 24″ exhaust fan, ½ h.p. motor, discharges 2400 cu. ft. of air per minute.

Seattle, Wash. Underground. Pipe passage 2′ wide around three sides. Men, two rooms, 30′×12′ and 40′×12′, and anteroom 12′×15′ with three book-black chairs and cigar counter. Ten free toilets and 6 pay toilets, 10 lavatories, 18 urinals, 1 sink. Women's room 30′×12′, 7 free toilets and 2 pay, 6 lavatories and 1 sink; anteroom 12′×15′, 3 boot-black chairs, counter for sale of toilet articles. All floors terrazzo, sloping to center drain in each room. Walls, 6′ wainscot of white 6″ tile. Stalls divided by marble on nickel-plated legs. Walls above tiling, and ceilings, Keene's cement, ivory tint. In surrounding passage, 3 steam coils for heating supplied from central station; passage connected with main rooms by bronze gratings 8″ above floor at 6′ intervals; also radiators in rooms for very cold weather. Ventilating pipes have openings beneath the seat of every toilet; 4 motor-driven fans drive air out of 4 stacks at rate of 48,000 cu. ft. per minute. Lighting by 25 2-light electric fixtures. To accommodate 10,000 in eighteen hours. Cost $24,506.

Cincinnati. Above ground. Brick, concrete foundation. In basement, water heater for heating building and supplying lavatories. Men's room, 17′×36′, women's room the same; passage for pipes between. Four public and one pay toilet on each side, 3 urinals on men's. On each side, bubbling drinking fountain, 4 lavatories and slop sinks. Walls wainscoted with white vitrified glazed tiles 3″×6″, with 2″ cove base of same material. Plumbing cost $1000; heating $600.

Springfield, Mass. Underground. 70′×30′, oval in plan, surrounded by passage 2′ wide. Men, 7 free toilets (one combination adult and juvenile) and 3 pay; 5 urinals, 3 lavatories and telephone booth. Women's side, 7 free toilets (one combination) and 2 pay, 2 lavatories and telephone booth. Drinking fountain in each room. Ventilation, exhaust fan with belt-connected motor, intake fan with direct-connected motor, change air every five minutes. Fresh air distributed through brass registers in ceiling; foul air taken from rear of each toilet. Floor, terrazzo with integral cove base 6″ high. Wainscot 6′ 8″ high of structural glass; stall partitions of same. Toilets of seat action type. All exposed metal, golden brass, which may be scoured. Stall doors held open by spring hinges.

Art. 40. Public Baths

Public baths are being built in an increasing number of cities and are recognized as a necessity in the larger ones. A New York state law passed in 1895 required all cities of 50,000 population

and over to operate free baths throughout the year. More than 50 cities of the United States now operate public baths.

These may be floating or stationary in river, lake or ocean (in which case they cannot be used in winter in Northern climates), or may be in a building in any part of a city. The bath may be in the form of a plunge or swimming pool, a tub, or a shower, rain, spray or needle bath. Most bath houses include all three of these, although some omit the pool, and most permit only invalids and other feeble persons to use the tubs.

The shower or needle bath is now the most commonly used, for it cleanses as well if not better than the tub; takes only 18 to 25 gallons of water as compared with 45 to 70 gallons for a tub bath; there is danger of infection from unclean tubs, and there is expense and time lost in cleaning them after each bath; the tub requires twice as much space and is more likely to be put out of order; and there is less danger of taking cold after a shower bath.

A pool usually is of a size requiring 50,000 to 100,000 gallons of water, which should be renewed at least once a day and kept at a temperature of 76° to 80°. It therefore requires as much water as 2500 to 6000 bathers using shower baths. In a few baths the water is not renewed daily, but is being continuously withdrawn, filtered and returned.

Because of the moisture, steam and use by all classes and conditions of humanity, the bathing building should be constructed with a special view to cleanliness and sanitation. No wood should be used in floors or in contact with a floor, and the less there is in the building the better. A building built throughout of stone or brick masonry, concrete, terrazzo, slate or marble, glass and metal is the ideal construction. The floors should be of concrete or terrazzo in all parts of the building, unless perhaps the waiting room and office. The pool should be of reinforced concrete, waterproof construction, and is usually and preferably lined with enameled tile. White is the common color for these tiles, but a pale green shows water stain less (as from iron in the water) and gives the water an appearance of inviting coolness.

A public bath house should have a waiting room with an office or desk with attendant just inside the entrance, where valuables may be checked, soap or towels provided (free or for a small sum), instructions given and a dressing room assigned. From this should open the dressing rooms and shower baths, and from these the plunge room (if any). There should be two sections of dressing and bath rooms, separated by a solid partition, or else separate hours or days assigned to the two sexes. Some baths have two plunges also, but the majority have but one, giving the use of it to females on certain designated hours or days. It should be impossible for any one to enter the plunge room without first cleansing themselves by a showerbath, and there should therefore be but one or two entrances to the plunge room or else to the pool itself, with an attendant always present to see that no uncleansed person passes.

Ordinarily twenty to thirty minutes is the time allowed for use of a dressing room, although this may be extended during certain hours when there is less demand for them. The capacity of the house is thus gauged, each room permitting 16 to 24 baths during eight hours of constant use.

Where separate baths are provided for the two sexes, more are commonly provided for men than for women. In New York there are, in all of the baths, a total of 904 showers for males and 395 for women; 23 tubs for males, and 55 for women. There were 3,350,737 baths taken by males in 1913, and 2,202,526 by females, an average of 3734 per appliance by males and 5795 by females; the total baths by females varying from 50 to 80 per cent of those by males in the several bath houses. Considering that women cannot generally dress as rapidly as men, it would seem desirable to provide nearly if not quite as many bathing appliances for females as for males.

The New York baths are used an average of $11\frac{1}{2}$ baths per day per appliance, and at one women's bath the rate was $26\frac{1}{2}$ per appliance in 1913; or, at twenty minutes per bath, a continuous succession at this rate for about nine hours every day

in the year. Probably during hot weather the number per day was at least one-third greater.

The waiting room should have seats for those who are waiting their turns at the baths, with capacity for say 50 per cent as many persons as baths.

The *bath room* and dressing room are generally combined, although in some cases there are two to four dressing rooms to each bath, since undressing and dressing take three or four times as long as the bath itself. The dressing room is made $3\frac{1}{2}$ ft. square or $3\frac{1}{2} \times 4$ ft. The shower room is generally $3\frac{1}{2}$ ft. square. Occasionally 6 in. is added to each of these dimensions. A room with $5\frac{1}{2}$-ft. tub must be about 7×6, this being dressing room also. It is economical to arrange the baths in rows, back to back, as then the same water pipes and drains serve both. Where there are several dressing rooms to a bath, the baths may be arranged in groups of four, with the dressing rooms surrounding and facing them.

The floor of the shower bath should be depressed about 6 in., with that of the dressing room sloping slightly toward it, and be provided with a drain opening covered with a strainer. It is desirable to so regulate the size of this, or provide an overflow, etc., that the water will stand 2 or 3 in. deep while the shower is operating, but drain completely in a few seconds afterward.

The floor should be of cement, asphalt, terrazzo or unglazed tile, and waterproof construction. The walls, partitions and ceiling should be of non-porous material and one not readily destroyed by soap, steam vapor or water. There should be no overhead pipes to " sweat " or drip steam which condenses on them. The partitions are generally raised above the floor 6 to 12 in. and rise to a point about 7 ft. above the floor. Above this it is well to provide a strong wire netting reaching the ceiling, to prevent the occupant of one room stealing clothing, etc., from an adjacent one. The partitions may be of slate, marble, alberene, annealed glass, tile or enameled iron. If the last, care must be exercised ever after to renew the enameling wherever it may chip. Tile takes up more space than the others.

There is generally a partition across half the line separating the bath and dressing rooms, with a curtain of rubber or duck filling the remainder. In the dressing room, generally in the corner next to the bath room, is a seat, and on the same side of the room one or two clothes hooks. The door may be of wood.

FIG. 112.—Public Bath House. Netting Over Tops of Stalls to Prevent Pilfering.

solid or slatted, clearing the floor by about a foot and reaching to $6\frac{1}{2}$ or 7 ft. above the floor, opening inward, provided with an inner latch and an outer lock. Also preferably with a spring hinge which holds it open when the room is not occupied.

The *pool* may be of almost any size, although probably

20×40 ft. would be the smallest desirable. New York's 23rd street bath has a pool 25×65 ft. 5 in. Toronto's Harrison bath has one 26×59 ft. Generally the pool is 8 ft. deep at one end for swimmers, but is reduced to 4 or 5 ft. at the other end for those who do not swim. Steps or ladder are provided at the shallow end or at both. Overflows are provided in the walls, and these are preferably so constructed that they can be used as cuspidors by the bathers.

A bronze hand rail along the sides about a foot above the water is desirable. In some cases there is a railing around the pool above the floor, but not usually.

Either the floor surrounding the pool, which should be 3 to 5 ft. wide, should slope away from the pool to a gutter in the rear, with a nozing raised an inch or two all around the pool to prevent dirt being washed into the pool, or the floor may slope toward the pool and a gutter be formed in the wall of the pool about a foot below the floor to catch the wash from the floor. Some of the latest pools have such gutter 6 in. wide and 6 in. deep with the bottom semi-circular in section, 16 in. below the floor, the outer edge of the gutter being rounded with a 2-in. radius and serving instead of a hand rail.

The walls of the pool in one installation are of 12 in. of reinforced concrete, on which is laid a waterproofing of five layers of waterproof felt swabbed with asphalt. Outside this is an 8-in. brick wall faced with glazed tile. The felt is fastened into the wall at intervals to prevent its slipping.

While concrete may be used for the floors, terrazzo is probably the best floor for a moderate price. Unglazed tile also may be used. In some baths asphalt is used because less cold to the feet. In the dressing rooms the same floor is generally most satisfactory. Wooden slats absorb dirty water and decay, and require labor to keep clean. Rubber mats are expensive and also need cleaning. At all points where floor and wall meet a cove is desirable, as angles are difficult to keep absolutely clean. Throughout the house the floors should slope to drains or gutters so that the whole floor, if flushed out with a hose, will drain

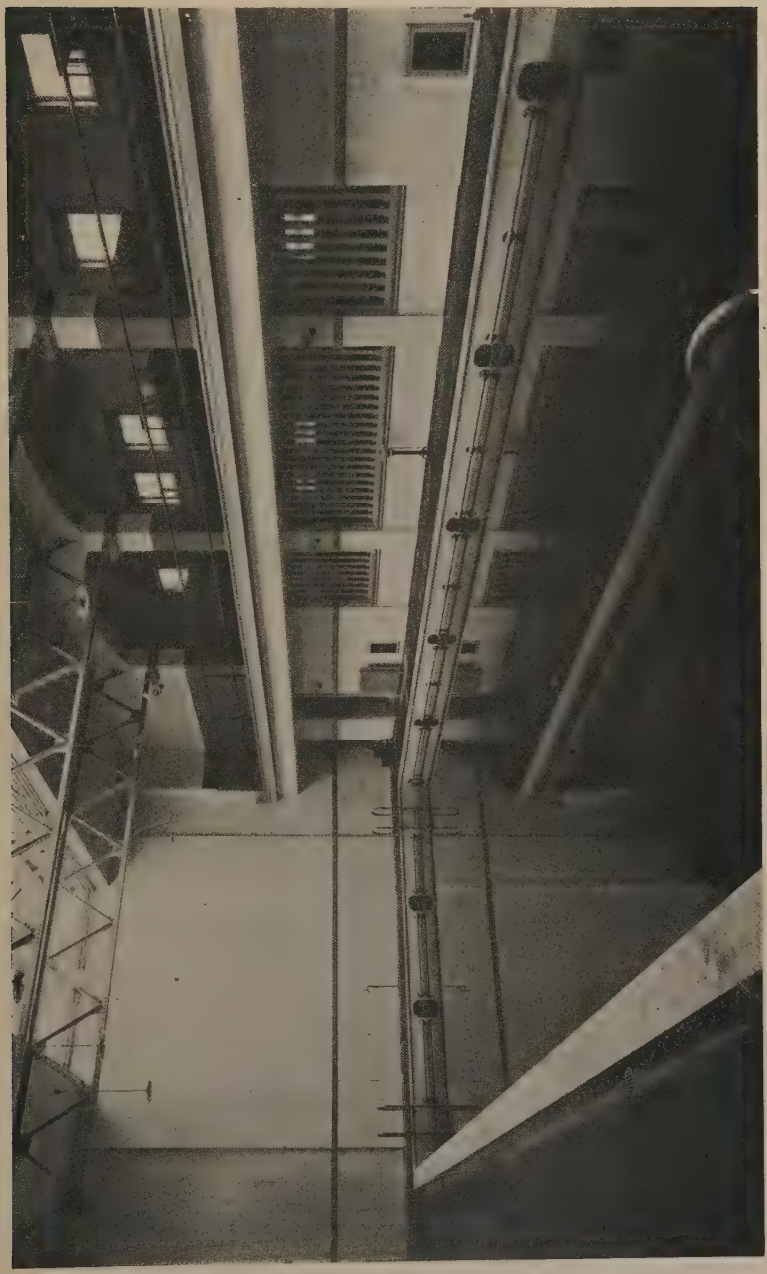


FIG. 113.—Pool in Public Bath, Toronto, Ontario.

quickly. Open gutters running the length of the room are less care and more sanitary than drains with numerous floor openings. All iron work exposed in the bathing rooms should be heavily galvanized or painted with five coats of bath tub enamel, unless it is to have a non-conducting covering.

A few cities have *out-of-doors pools* with dressing rooms facing them. As the feet of bathers using such pools are apt to be dirty on entering the dressing rooms, provision should be made for cleaning them. Perhaps the best plan is to have a gutter, about 4 ft. wide and through which about 2 or 3 in. of water is always flowing, passing in front of all dressing rooms, with hard, clean flooring between the gutter and rooms. One or two plants have the dressing rooms in a building with only one entrance, at which is such a gutter and also a spray filling the entire doorway, this not only removing all loose dirt from the bather, but preventing non-bathers from entering the building. An out-door pool may have a shallow wading beach at one end, covered with clean gravel, and be deep enough for swimming at the other.

The *plumbing* for a bathing house should be of the best, for it is to receive abundant use. All drain and water pipes should be of abundant size, so that there may be no delay from this cause in putting the bathers through on schedule time. This applies especially to the pool and to the bath tubs. An 8-in. water pipe to the house and a 6-in. to the pool was used in one installation, but this seems unnecessarily large.

It is a good plan to introduce cold water into the pool just above the surface and hot water at the bottom unless the water is heated to just the right temperature before it enters the pool. Heating the pool by steam pipes around the bottom is objectionable as it may burn the bathers.

For the shower bath, the water may be kept heated to the desired temperature in a tank, but it is generally considered better to bring both hot and cold water to each bath and allow the bather to regulate the temperature, using non-scalding faucets by which the cold water must be turned on before the

hot. The spray is set about 7 ft. above the floor at an angle of about 20° with the vertical. The holes in the face of the spray should be about $\frac{5}{64}$ or $\frac{3}{32}$ of an inch in diameter. Smaller holes cause the fine jets to sting the flesh. Galvanizing is apt to wear off, and pipes of brass or red metal are preferred by some. Black iron should not be used for any plumbing exposed in the bath room.

For heating water for the bath, any hot water heater may be used, but perhaps the most common is the Tobey, in which steam is used to heat the water, and which has an automatic steam shut-off, by which the steam valve is closed automatically when no hot water is being drawn, and the amount of steam used is thus adjusted, preventing overheating of the water. Another device used is a German invention introduced about twenty years ago called the "gegenstrom" apparatus, in which steam enters a central pipe and the cold water rises to the spray through a larger pipe which encloses the steam pipe; the steam condensing in the inner pipe and flowing away. Either of these of course requires a steam heater. If a municipal electric or other steam plant is convenient, the exhaust steam from this may be used. The water for the swimming tank may be heated in the same way, if it is drawn off and filtered continuously; but if renewed once a day, it is best to heat it in a special large hot water heater.

The building should be heated in winter to 75° to 80°, and ventilated by fan at all times. High side windows are preferable to skylights, as the latter admit the sun too freely in hot weather. There should be water closets and urinals in the bathing portion of the house; also drinking fountains.

There should be closets for storing towels, soap, etc. A laundry and drying room are desirable, although the washing can of course be contracted for by a local laundry. The general appearance of the building should be unpretentious and all its details be simple, as the reverse would tend to keep poor people away. There should be as few as possible of removable articles or portions of fixtures, which the thieving, malicious or mischievous could detach.

Floating Baths. A public bath is most serviceable when it is within a half mile of the most citizens whose homes contain no baths. This limits the serviceability of floating baths; but on the other hand they are more attractive to many, especially children, and are much cheaper than those in buildings. About fifteen years ago Boston had 12 floating baths; New York, 20; Hartford, Conn., 2; and several other cities had one each. Many of these have had to be abandoned because of sewage pollution of the water; but where this does not interfere with such baths, they are well worth their low cost.

The general construction of the floating bath is that of a flooring floated by water tight tanks or casks; carrying dressing rooms around the outside edge on all sides (except the office, which provides entrance from the gang plank), and with a large opening in the center for the pool. This last is built of open slat work to permit the water to flow through freely. The whole is built of wood and is about 60 to 65 by 90 to 100 ft. outside dimensions. The tank is about 40×70 ft. leaving 10 to 15 ft. on each side for platform and dressing rooms. The tank is about 5 ft. deep; the openings between slats $1\frac{1}{2}$ in. The tank is not roofed over, unless near a bridge or tall buildings. The bath is moored to the bank or wharf, and is run up onto land before the river freezes over in winter. Such a bath cost about $5000 to $15,000, depending on the size. One attendant operates it for about five months a year. Fees charged for soap and towels (5 cents) and bathing suits (5 or 10 cents) just about cover the cost of attendance. One or two cities have built stationary bath houses on piles, similar in general construction to the above.

Swimming pools have been built by several cities. A pool with two or three polling booths fitted up temporarily as dressing rooms has given good service. The city of Erie, Pa., has a swimming pool built by the water department on land reclaimed along the harbor, the pool being 75×155 ft., and $1\frac{1}{2}$ ft. to 6 ft. 9 in. deep, lined with concrete. On one side are 34 dressing rooms, each $3\frac{1}{2}$×5 ft. St. Louis has what is believed to be the largest artificial swimming pool in the world, in form a circle

440 ft. in diameter divided by a walk into a large deep pool of 99,743 sq. ft. and a smaller shallow one of 37,000 sq. ft. The former has a maximum depth of 10 ft., the latter of $4\frac{1}{2}$ ft. The pools are lined with concrete and an artificial beach made with 700 tons of fine white sand. On one side are 236 dressing rooms and 288 children's lockers, all in a frame structure. In the center of the pool are a concrete platform, light standard and diving tower 12 ft. high. The cost of the pool was $23,000 and of the dressing rooms $37,000.

CHAPTER X

PARKS, CEMETERIES AND SHADE TREES

Art. 41. Parks and Parkways

The parks found in a city vary in area from a small open space at the intersection of a diagonal street with a rectangular street system, to one of several hundred acres in extent. Parkways include the parked strip along a sidewalk and the much more extensive strip in a boulevard or other ornamental street. The laying out of any of these is a matter of landscape architecture; but that of the smaller parks and many of the parkways is frequently assigned to the city engineer; and the construction methods of all are matters of engineering, and will be considered herein for that reason.

Small parks seldom exceed three or four city blocks in area, and are more commonly one block or less. Their purpose is to furnish breathing spots convenient to all citizens, where they may spend a few minutes of leisure; also to afford playgrounds for children. It has been held that there should be such a park within a quarter mile of every residence in a city, giving four or five per square mile of city area. Areas for these parks should be reserved at proper intervals when making the street plan. As each is reached by building development, design the paths and plant trees; fencing in the whole park, temporarily, since it will not be needed until the area around and beyond it is well built up.

The small park is of four general classes: (1) The small plot of open ground containing no walks, but only a statue, fountain, clump of trees or shrubbery, enclosed by intersecting streets. (2) The business section park, removed some distance from

residences and used chiefly as a resting place at noon for employees and to furnish light, air and pleasant prospect to a district of high buildings. (3) The residence section park, used by women and children, and in the evening and Sundays by men. (4) The playground park, similar to the former but with the added feature of playgrounds made more or less prominent.

The first should generally be set off from the sidewalk by an inconspicuous fence (of iron pickets, chains or other), or at least by a stone or concrete curb. Flowers are not generally desirable unless the area is at least 2000 sq. ft., but shrubs or lawn is preferable. No provisions are made for resting in such parks.

The *business section* park should not in any way inconvenience either foot or vehicular traffic, but both roadway and sidewalk of bordering or intersecting streets should be carried by or through uninterrupted. In addition, a space for parking automobiles should be provided, if practicable. If the park occupies as much as a block in area, walks should be carried through it. Some make these winding, to discourage their use as thoroughfares; but in such a park only formal, geometrical treatment is appropriate, and diagonals to furnish short cuts offer the advantage of convenience to traffic in addition to those possessed by winding paths. Paths in these parks should be of concrete or other durable material.

There should be shade trees in abundance and as many seats as can be placed conveniently. A pleasant day will find all such seats in Madison Square, New York, Bennett Park, Buffalo, Jefferson Square, San Francisco, etc., occupied a considerable part of the time. The seats are preferably placed along one or both edges of the walks, which are made sufficiently wide for that purpose. If the seats are on the sodded portion, the grass will be worn in front of them, and it will be more difficult to clean up papers, peanut shells and other rubbish dropped by those using the seats. For a much-used park this calls for 10 ft. of walk clear for pedestrians, and $3\frac{1}{2}$ or 4 ft. for each row of seats. It is

desirable to have a convenience station in each park of this class. There may also be, in one or two of these parks, a stand to be used for band concerts, mass meetings and similar purposes.

A *residence section* park should be especially designed for women and children, and using it as a thoroughfare should be discouraged. The walks therefore should be curved, and may even be so laid out that it is impossible to pass diagonally through it. Here also there should be abundant shade and seats; a comfort station, drinking fountain and shelter also should be provided. It is desirable that sand boxes, swings and other diversions for the younger children be located in each park (preferably well back from the sidewalk). A fence surrounding the park, with several entrances (but without gates), adds to the safety and sense of seclusion and rest. The paths here may be narrower, but wide areas of either pavement or lawn should be provided for groups of baby carriages. Gravel walks are often used for these parks.

A regular *playground*, preferably in the center of the park, is considered most desirable. Such a park is too small for a ball field, besides which this would be dangerous for the small children and attract a boisterous element which is undesirable. Especially in the poorer sections, the whole park may be given over to playground, to be in charge of a play instructor; except that a path, narrow strip of lawn and seats are desirable around the border for the mothers; and a hedge surrounding the whole to discourage idle spectators is suggested. A good-sized shelter for rainy days or sudden showers and a comfort station should be provided, and public baths are very desirable. It has been suggested that a playground be placed in the center of each block of residences, a few feet taken from the rear of each lot giving in the aggregate a fair-sized area, where the children of that block would be safe from danger and where their mothers can easily reach them. Such playgrounds could well be included in the original street plan.

PARK AREA IN SEVERAL LARGE CITIES

City	Population	Area of Parks, Acres	No. of Persons per Acre of Park	Ratio of Park Area to City Area, Per Cent	Cost of Parks per Capita
New York	5,333,539	8,498	628	4.1	
Manhattan	2,331,542	1,479	1,576	.....	$0.58
Brooklyn	1,634,351	1,700	961	.....	.65
Bronx	430,980	4,170	103	.....	1.30
Queens	284,041	1,149	247	.....	.65
Baltimore	579,590	2,320	250	12.0	1.18
Detroit	546,183	1,244	439	5.0	.91
Los Angeles	452,140	4,000	113	10.2	.56
Minneapolis	343,466	3,813	90	12.1	2.29
Seattle	313,029	1,803	174	6.9	1.93
Kansas City	284,567	3,006	95	18.0	3.96
Indianapolis	259,820	1,720	151	8.6	1.57
Rochester	245,077	1,603	153	13.1	.81
Spokane	135,657	1,939	70	15.3	2.14
Hartford	107,521	1,335	80	12.2	.84
Tacoma	103,418	1,150	90	6.0	1.11

Large Parks. Every city should reserve space for at least one large urban park, gradually developing it as the growth of the city drives the country further from its center. This park should contain at least 100 acres; should be beyond the furthest reach of the business center but accessible (with not more than one car fare to pay) from all residence sections. The site should not cut off any important thorofares. The more diversified the ground surface the better. Water is desirable. In general, the less desirable an area is for building purposes the better adapted it is for a park, which greatly simplifies the selection and reduces the cost. A stream with steep banks or in a deep, narrow valley is a difficult proposition for land development, but is ideal for a park. The cost to the city of grading streets across such a valley, building culverts or bridges, etc., may easily be greater than that required to develop the park; and the owners of property which such valley crosses should be glad to donate it to the city in view of the increased value the park would give to the rest of their property. A hillside, also, too steep for building purposes, may be used as a park. Swampy land can be used by excavating a

stream channel and lakes, using the excavated soil to raise the level of the remaining area.

Trees should be planted closely around the border of the park to shut off view of surrounding buildings and streets. For the same reason a depressed location is better than an elevated one. The park should be at least wide enough to permit a road and a path to wind through it between wide borders of trees and shrubbery. Do not remove a tree or shrub from the area until the plan is perfected, and utilize as many of these as possible in the plan.

Park roads should be given an easy, natural curvature, caused by following the surface contour (the road should contain as few and as light cuts and fills as possible) or a stream or shore of a pond; or occasions for curves may be created by artificial objects such as buildings, monuments, shrubbery masses, etc., or by the location of playgrounds or other subdivisions of the area.

Formal curbs should be omitted. Unless there is a steep upward slope at the side of the road, or much drainage water to be carried (and this should be prevented by frequent inlets), a sod gutter is preferable to a hard one. The slope of the road is continued for 3 to 5 ft. beyond the edge of the pavement, then an upward slope provided, producing a gutter 4 to 6 in. deep at that distance from the pavement, the entire area beyond the pavement edge being sodded. Water will not erode the sod when it is well rooted, the grass preventing high velocities in small flows. If mud is carried by the water, it will be deposited in and disfigure the grass, but there should be no erosion to cause mud in a well-kept park. Park inlets to the sewer should be placed at intervals of 200 or 300 ft. in the gutters. Where there is a steep slope shedding water rapidly and in volume onto the roadway, a cobble or brick gutter is desirable, and the inlets should generally have catchbasins under them.

Every opportunity to arrest attention or invite a lingering (a view-point, skating and boating pond, tennis or baseball ground, etc.) should be taken advantage of, and the roadway

widened here to provide for vehicles stopping without interrupting traffic. In addition to this, there should be considerable areas for parking automobiles and bicycles. Roads should not reach all parts of the park, but there should be some accessible only by foot.

Every important drive should be accompanied by a walk, or people will walk in the drive, to their danger and the inconvenience of drivers. Paths and drives should be so laid out as to cross each other at as few points as possible. Where there are desirable views, the walks should be in front of the drives, for those in vehicles can see over the heads of those on foot.

Before making a park plan, a contour map is essential, showing also trees, large rocks, ledges, all bodies of water and other natural features. The kind, diameter of trunk and spread of each tree should be noted. Do the least possible grading; not much is needed in most cases, except for treating swampy places; but give every part some slope toward a stream or gutter, to remove surface water. In locating roads, save all the desirable trees possible. Roads should lead to all important points, especially to such as give views of the surrounding country or of other portions of the park. The grades should be light, to prevent the roads being washed by rain and worn excessively by traffic. But there should be some grade to every road and path, to provide drainage to sewer inlets. About 20 ft. is ample width for ordinary drives, 30 ft. for the more important ones; this both to save in cost and add to rural appearance.

Trees should not be so close together that their shade will destroy the grass. Streams should not be straightened nor walled in, but their banks should be raised where swampy, or graded down if more than 3 or 4 ft. high. If a retaining wall is necessary at any point, it should be fenced.

Occasional ponds or lakes should be made by widening streams. If topography permits, there should be a body of water large enough for skating (an acre or more) and for rowing, the stream also being widened and used for rowing; also a wading pool for children. In any pond or lake the design should provide

for a current in all parts to prevent stagnation. The wading pool, however, may be artificial, with a bottom of concrete, or of clay puddle covered with clean sand, and fed by water from the mains which flows continuously or is renewed daily. Boating lakes should be shelved gradually to a depth of 18 to 24 in. at 8 or 10 ft. from shore, except at the boat dock. A depth of 4 or 5 ft. over the body of the lake is ample for rowing and makes drowning accidents improbable; but if the depth is less than 8 ft. water plants are apt to prove a nuisance. For skating and other winter sports, tennis courts, ball grounds or other level areas may be flooded to a depth of a foot or two in winter.

Where sufficient level land is obtainable, there should be areas set aside for tennis courts and ball grounds. The latter are preferably placed at one end of the park so as to interfere as little as possible with the quiet and seclusion of the park proper. If there is sufficient area, it is desirable to move the tennis courts alternately from one area to another, so as to prevent killing the grass. Otherwise clay courts are desirable.

Parkways, in the form at least of 5-ft. planting strips or wider, are desirable in all but business streets, where the incessant crossing from side to side would prevent the growth of grass and foot traffic be hindered by the extra width required for parking. Parking may be of any width from 5 ft. up. It may be between the house and the sidewalk, in the centre of the street, or between the roadway and sidewalk; but where the street is 100 ft. or more wide and the parking is to be permanent, a central parkway is much more attractive in appearance and is generally preferable for other reasons, such as the possibility of approaching nearer to the houses by carriages (especially desirable when the absence of alleys necessitates the delivery of coal and other articles at the front of the house). The Mystic Valley (Boston) parkway has a 40 ft. roadway, then a 6 ft. lawn and 9 ft. sidewalk on each side. The Blue Hills (Boston) parkway is a street 120 ft. wide, a 32 ft. strip of lawn separating a 26 ft. and a 36 ft. roadway. A parkway planned by Olmsted for East Orange, N. J., has 10 ft.

lawn, then 12 ft. sidewalk and 30 ft. driveway on each side of a 46 ft. central grass plot. Oxford St., Rochester, has a 17 ft. roadway each side of a magnolia-planted central park. In Columbus, Ga., several 132 ft. streets have 30 to 36 ft. central parks, 28 to 32 ft. driveways, and 17 to 20 ft. sidewalks, with a double row of shade-trees in parks and a single row along sidewalks.

On streets where the roadway is graded down below the sidewalk, the side parks are especially desirable, being made to slope from gutter to sidewalk, while the narrowing of the roadway decreases the excavation necessary.

It is desirable to connect all the city parks, or afford a main approach to an only park, by a parkway, which may be a single street or a route winding through several streets. The banks of a stream form an excellent location for a parkway, the banks being sodded and planted with trees, which is cheaper than walling or covering the stream. A path, possibly winding, may follow close to the bank, but the principal sidewalk will be across the road from the stream. As a general rule both banks of every stream within city limits should be parked, except such portions as may be occupied by users of water power; the banks thus being kept clean of ash dumps and offensive and unsightly buildings.

It is especially desirable that the streets in front of factories be parked, to afford air, light and pleasure to the workers.

Roads. Heavy traffic or teaming should be excluded from park roads, and the paving may be lighter, on that account, than on streets or highways. The surface must provide for rapid traffic, largely by automobile. Dust is objectionable, both to those using the park and because it injures and disfigures vegetation. For both of these reasons, water-bound macadam and gravel roads are eliminated, unless they receive a bituminous surface treatment. The surface should be smooth but not slippery, firm but not hard, easily cleaned, without unpleasant glare, and with as much of a rural appearance as possible. Of the paving materials in common use at present,

bituminous concrete or macadam, or bituminous-surfaced macadam, seem to best meet these requirements.

For the width of a park road, 20 ft. is generally ample, except on much-used main drives, where double this may be required. The road should be crowned as for streets.

A park road through a parkway should be straight and formal, with gutters and curbs at the sides, and preferably lined with trees uniformly spaced in straight rows.

Paths may be of gravel or concrete; the former for less frequented ones, the latter for the main walks. The construction would be as for streets, described in Article 11. As in the case of driveways, curves are preferable to straight lines; and sod gutters and other construction which suggests country rather than city conditions should be used where possible.

Drainage. Roads should be underdrained and surface water removed, and for this purpose a drainage system is necessary. The pipes are generally laid under the sod at the side of the road rather than under the driveway, as less damage is done to the former in digging down to the drain to remove obstructions or for other purposes. The depth need be only 3 or 4 ft. in most cases, except as securing a sufficient fall to an outlet requires deeper cuts. The capacity and size are calculated as for storm sewers, but a low coefficient of run-off can be used.

Swampy areas should be underdrained, as is done for farm lands, by regular drain tile distributed in parallel lines over the area, or by " blind " drains of brush or stone similarly located. A rule of long standing is to place drains 20 ft. apart if 3 ft. deep, 40 ft. if 4 ft. deep, and 80 ft. if 5 ft. deep; but this will vary with the readiness with which the soil gives up water.

Water Areas. In making bathing pools, skating and boating ponds, or banks of stream channels in swampy or mucky land, the following plan is recommended. Drive a continuous line of piling of 4 in. or 6 in. round piles at the proposed edge of the water, sending them well into solid soil or at least three times as

deep into muck as the proposed depth of water. Gain a waling timber into these near their tops and on the side facing the water and drive batter piles in front at intervals of about 5 ft., at the flattest slope possible and so as to butt against the wale. (The sheet pile can be omitted where each of these batter piles comes and driven after the latter has been driven through the opening, sawed off, and the wale set.) This holds the surrounding muck from sliding into the excavation. The muck in the pond or channel is then excavated to a uniform depth about 6 in. greater than the depth of pond or stream, and good soil is dumped around the edge of the excavation and given a slope of 2 or 3 to 1. This will probably force up the muck in the center, but the filling around the edges is continued until this rising ceases. Then the muck in the center is again excavated to grade and covered with about 6 in. of good soil; and 2 in. of gravel is placed over the entire bottom, if it is a swimming pool, to prevent the feet of bathers getting dirty. The area around the pool also is graded and covered with top soil. It is a good plan, before placing the good soil over the muck bottom, to lay on this bottom a floor of boards of hemlock or other cheap wood.

Sprinkling. The large areas of lawns in a park require a great deal of sprinkling, in most climates. To facilitate this, several cities have placed a sprinkler system throughout the park, the pipes being a foot or two below the surface, connected to which are sprinkler nozzles at the surface of the lawn. Opening one valve then serves to sprinkle a considerable area. In a climate where freezing weather occurs, such a sprinkler system should be laid carefully to such grades that the entire system of piping can be drained out in the fall. " Black iron " pipe should not be used, as they rust rapidly, which not only shortens their life but clogs the sprinklers.

Lighting parks is generally done by electricity (gas leaking from mains is injurious to vegetation), the wires being carried in cables laid a foot or two beneath the sod. The standards should be ornamental. The character and amount of lighting should be about the same as for residence streets.

Art. 42. Cemeteries

About 350 municipalities of more than 3000 population own cemeteries, the north central states containing 100 of these, the New England states 73, and the remainder being more or less uniformly scattered over the country.

Assuming a death rate of 17 per thousand and a doubling of the population every thirty years, and an average of 1000 bodies buried per acre, this would require about 14 acres for each thousand of the present population during the next 100 years; or say a square mile for each 37,000 of present population. This means that a large amount of land must be devoted to this purpose, unless cremation or depositing in above-surface vaults be practiced. The latter is more or less common in some Southern countries, especially where the ground water is near the surface. Such vaults may be found at New Orleans.

A cemetery must be located where neither rock nor ground water comes within 7 or 8 ft. of the surface. Rolling, wooded land is desirable, as the general treatment should be similar to that of a park. More drives are required, as every part of the ground must be reached by hearses and carriages; but the drives can be paved with macadam or gravel, for only slow driving will be permitted, and there will be comparatively little even of that.

In laying out the drives and paths, the aim should be to avoid regularity as far as possible, as in a park; but the plan is to a certain extent controlled by the subdivision of the entire area into plots, all of which must be reached by at least a path, and a drive should pass within 50 ft. of every lot. The larger lots may be made somewhat irregular and placed on elevations or prominent points, since these will probably contain the more elaborate monuments, flower beds and other ornamental features. The smaller lots will need to be more or less rectangular in shape and uniform in depth (about 12 or 24 ft.), and here the roads must run nearly parallel; but variety should be given by public plots of different sizes and shapes containing flower beds,

clumps of ornamental shrubbery, etc., placed with this idea in view. These small, regular lots will ordinarily be placed on the lower and flatter lands.

Very low land is generally useless for burial purposes because of the nearness of ground water to the surface. If such is included in the cemetery, it may be parked, planted to flowers and in general treated as a purely ornamental adjunct of the cemetery.

Art. 43. Shade Trees

Shade trees add greatly to the comfort and pleasure of urban life, cooling the streets in summer, purifying the air, and relieving the harshness of the perspective of streets built up with solid rows of houses. Dealers in real estate know that healthy, well-shaped trees add to the value of property. The New York County Medical Society stated, in a resolution, " that one of the most effective means for mitigating the intense heat of the summer months and diminishing the death rate among children is the cultivation of an adequate number of trees in the streets."

Shade trees cannot be grown satisfactorily in every street unless located wisely. A tree should, if possible, be located no nearer a building than half its height (to the eaves at the point opposite the tree), and certainly not less than a quarter of its height. In the case of a narrow street with tall buildings this would make a central parkway the only location for trees, and the space for this probably could not be spared. In fact, in a narrow street in a business district the space required by trees and the exposed soil for 2 or 3 ft. around each cannot be spared, and trees cannot often be grown there.

The relative advantages of locating a planting strip with trees on the inside and outside of the walk respectively has already been discussed. It is claimed that they grow better on the lawn side of the walk than on the roadway side because the soil is generally better, receives more moisture and air, and

the tree trunks are less subject to damage from horses' teeth and wheel hubs. But the appearance of the street is not so good unless the roadway and sidewalks are narrow and the total width between the two rows of trees does not exceed 40 or 50 ft.

The more moisture and air a tree can receive the better (within any limits likely to be experienced on a street). But the soil should drain readily also, so that the roots will not be continually wet; except for certain species which may be selected for their preference for wet ground.

The species recommended by the Park Commission of Detroit, Mich., for that city are the American elm, Scotch elm, Oriental or American plane, pin oak, red oak, Norway maple, hard maple, and white ash or ailanthus. The last named may, it is said, be grown in the vicinity of large factories and railroads, as it is highly resistant to gas and smoke.

William Solotaroff, in his " Shade Trees in Towns and Cities " (to which the author is indebted for most of the statements in the next few paragraphs) suggests that valuable advice on this subject can be had from the State Experiment Station in most states. He ranks the Norway maple as the best of the maples, with the sugar maple next. The red maple, however, is adapted to narrow streets because of its small size, and to rather moist soil. The white or silver maple is the poorest of the maples; the life is short, the wood is weak and brittle and the shape is poor for a shade tree.

The Carolina poplar he condemns outright. The wood is very weak and brittle; the tree is short-lived; the flowers are a nuisance; the tree is a lover of water and chokes sewer pipes if there is any opening in a joint. In Albany, N. Y., it has for years been a misdemeanor to permit such a tree on one's premises. The Lombardy poplar is sometimes used for narrow streets or for windbreaks, growing very tall and slender. It gives little shade and is short-lived.

Oaks are among the best shade trees obtainable for cities. They grow about as rapidly as hard maples, are strong, durable, beautiful and have practically no insect enemies. Washington,

D. C., has about five miles of streets planted with pin oaks. The red oak and scarlet oak are even more to be desired for beauty. The white oak is a slow grower and sheds leaves long into the winter.

The American elm is the most popular shade tree in the North. The horse-chestnut is not recommended. The Oriental plane combines to a greater degree than any other tree the characteristics of rapid growth with everything that is desirable in shade trees. The tulip is too large for any but the widest avenues.

For Southern states the live oak, water oak, willow oak and laurel oak, the laurel magnolia, pecan, camphor, and palmetto trees are recommended. Not as much study has been given to trees adapted to street use in the Southern as in the Northern states.

A commission of experts for Washington, D. C., gave the following requirements for shade trees: " (1) A somewhat compact stateliness and symmetry of growth, as distinguished from a low-spreading or pendant form, so that the stem may reach a sufficient height to allow free circulation of air below the branches. (2) An ample supply of expansive foliage of bright early spring verdure, and rich in the variety of colors and tints assumed during autumn. (3) Healthiness, so far as being exempt from constitutional diseases, as well as from maladies frequently engendered by peculiarities of soil and atmospheric impurities. (4) Cleanliness, characterized by a persistency of foliage during the summer, freedom from fading flowers, and exemption from the attacks of noxious insects. (5) It should be easily transplanted, of moderately vigorous growth, and not inclined to throw up shoots from the root or lower portion of the stem. A tree of extremely rapid growth is generally short-lived. (6) The branches should be elastic rather than brittle, that they may withstand heavy storms; and, lastly, there should be no offensive odor from foliage or flowers."

Rapid growth would be desirable were it not almost invariably accompanied by short life and softness of wood. William F. Fox, Superintendent of the New York State Forests, gave the

following as the diameters of trunk which would be attained in twenty years by the trees named:

	Inches Diameter		Inches Diameter
White or silver maple	18	Yellow locust	14
American elm	18	Hard maple	13
Sycamore or buttonball	17	Horse-chestnut	13
Tulip tree	18	Honey locust	13
Basswood	17	Red oak	13
Catalpa	16	Pin oak	13
Red maple	16	Scarlet oak	13
Ailanthus	16	White ash	12
Cucumber tree	15	White oak	11
Chestnut	14	Hackberry	10

Locating trees should be done systematically, and abutting owners who set out trees should be required to conform to instructions as to location. American elm trees should be set about 50 ft. apart; sugar maple, red oak, chestnut oak and Oriental plane, 45 ft.; Norway maple and red maple, 40 ft.; American linden and pin oak, 38 ft.; European linden, sweet gum and horse-chestnut, 35 ft.; ginko, catalpa and hackberry, 30 ft.; ailanthus and Carolina poplar, 28 ft. The above refer to average specimens allowed to grow to full size.

Unless the rows of trees are close together, trees in parallel rows should be placed opposite each other. In general, a tree should not be placed just at the corner of a street, but about 20 ft. back from the corner on each street. Trees should be kept at least 8 ft. away from lamp-posts and 10 ft. from fire hydrants. These rules as to corner location and avoiding posts, etc., will interfere with exact spacing at the intervals recommended, but such intervals should be approximated as nearly as practicable.

In some cases two kinds of trees, one of rapid and the other of slow growth, are alternated in each row, the former being removed as soon as they begin to interfere with the development of the permanent slow-growers. But all specimens in a stretch of street should be of the same kind and especially of the same size, to obtain the best effects. However, to offset the wholesale spread of tree disease as well as to obtain variety, as many good varieties of shade trees as possible should be planted in a city.

Tree planting should be planned for and systematized, as is done in the case of sewers and should be done for street paving. This plan will include, for each block of each street, the spacing, location relative to property line or curb, and kind and size of tree. (Ordinarily a tree three or four years old will be planted, but if the block under consideration needs only a few trees to fill up vacancies, the new ones should be as nearly as practicable the size of the old.) As a beginning, a survey should be made of all existing trees and their location plotted on a map, a record also being made of each tree, giving its kind, size and condition, each tree being assigned a number. In numbering, the street name may be given and the numbering be separate for each tree, numbers being also assigned to any spaces where trees may be placed in the future. When a tree is replaced, the new tree may be given the same number with a letter suffix. Thus—"Main 27a" would indicate that the original tree number 27 on Main street had been replaced.

Planting trees is, as a general thing, best done very early in the spring. Have the hole abundantly large. Use no fresh manure in the hole, but a mulch in the bottom is beneficial. Stake the trees substantially and protect them by a guard. A single stake reaching well to the top of the tree is desirable, driven firmly into the ground, to which the tree is fastened at two or three places by a $\frac{1}{4}$-in. manila rope passed through an 8 or 9-in. piece of $\frac{3}{4}$-in. rubber hose. For a guard, a good and cheap one is of No. 16 $\frac{1}{2}$-in. square wire mesh, which comes in rolls 20 in. wide, cut into 6-ft. lengths. One of these is bent into a cylinder around the tree, the edges fastened together by the wire ends, and a piece of $\frac{3}{4}$-in. rubber hose fastened at the inside top to prevent the wire rubbing the tree.

An open space at least 3 ft. square should be left unpaved around every tree to furnish ventilation and moisture. The more this area can be exceeded the better. If there is danger that the soil around the tree will be beaten down by the feet of pedestrians, it is well to place an iron grill or grating around the tree. These are generally made of four or six plates of cast-iron

set around the tree, placed level with the sidewalk and supported by stakes driven in the ground. The soil under the grill is hollowed out into a basin to collect water.

In some localities or climates and for some trees, artificial watering is necessary. This may be provided for by placing a line of 2-in. or 3-in. clay pipe a foot or 18 in. below the surface, either surrounding the tree or in a line 8 or 10 ft. long at one side of it. The joints are laid open and the pipe is surrounded with gravel or broken stone. At one end a T branch or bend, brought up to the ground surface and capped, furnishes opportunity to apply water to the soil through this pipe. Another plan is to provide two or three openings through the curb at the gutter level opposite each tree, through which the water from the roadway can enter, placing a bushel or so of broken stone back of each opening to hold the water. But the best plan is to keep the surface of the soil loosened up, and water from the surface.

Damage to trees is caused by horses gnawing the bark; therefore keep trees along the curb protected by guards.

Cutting off roots to carry curbs close to the trunk should not be permitted. Better carry the curb around in a projection, or omit the curb altogether at the tree.

Illuminating gas is fatal to any tree in time. Symptom—foliage turns yellow, wilts and falls from the tree; bark becomes loose; fungous growths appear. The only remedy is to stop the leakage in time; then dig a channel around the tree, loosen the soil about the roots, and wash the gas from it by watering freely.

Raising the ground level around a tree excludes air and kills it. A well should be left around the tree of as large diameter as possible; covered with a grating if desired. In a few years the roots will come to the surface around the well and the latter can then be filled.

The ground around a tree should not be lowered more than a foot unless the tree also is lowered or else removed. A row of trees can often be saved by leaving a sidewalk high, by building a wall around one side of each tree, etc., as explained in previous chapters.

Guy ropes tied to trees; a wire or wire rope left tied tightly around a tree; electric wires rubbing against a branch; dust and smoke which coat the leaves; these are some causes of injury to trees which should be prevented.

Legal Rights. A municipality has the legal right to remove any tree or part of a tree standing within the limits of a highway if the convenience of the public demand it. Suit may be brought by any citizen to restrain the municipality from removing a tree, but the only question the court can consider is whether public convenience requires it, the burden of proof resting with the complainant. It is the duty of the city to remove any tree or part of a tree which is a menace to the public safety, whether on public or private land; but in the latter case it is liable to the owner for all damages. It can remove any part of a tree extending over the boundary of a public highway. If a tree on private property is unsightly in comparison with the general appearance of the street, the municipality may remove it, but is liable to the owner for damages, and burden of proof of the necessity rests with the city.

A city is liable for damages to individuals injured by falling trees or branches if the city knew or could have known that the tree was unsafe.

A tree planted in a public highway by a private individual becomes at once public property; and a city can specify the kind and location of such planting. A private owner may not remove branches of a publicly-owned tree which overhang his property, nor a tree on his property if its branches overhang the highway; in each case the city has a joint interest in the tree. To a certain but indefinite extent it has a joint interest in all trees which, from their location, add to or detract from the appearance of the city as a whole.

Many if not all of the above common law provisions may be modified by laws of individual states.

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